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Attitudinal Responses to Changes in Noise Exposure in Residential Communities

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EXECUTIVE SUMMARY

Beginning in October of 1993, The National Aeronautics and Space Administration (NASA), in cooperation with the Federal Aviation Administration (FAA) and industry partners, launched the Advanced Subsonic Technology Program (AST). The AST program consists of five elements, one of which is Noise Reduction. Within the Noise Reduction element there are five sub-elements, one of which is "community noise.[1]" Looking toward the twenty-first century and forecasts of growth in the commercial aviation industry, the AST program goal is to apply all possible technology towards improving the capacity of the nation's airport and airways systems, while at the same time reducing environmental impact. To this end, the AST program includes a wide range of sub-elements, including (1) evaluation of high-lift aerodynamic systems to reduce airframe noise, and examination of possible noise-generating engine/wing interactions, (2) development and validation of interior noise reduction methods for quieting both cockpit and cabin, and (3) reduction of community noise impact through the application of new airplane technologies and operating procedures, enhanced accuracy of aircraft/airport noise prediction models, and a better understanding of human response to aircraft noise exposure variables. The tasks focusing on the improved understanding of human reaction encompass the current study.

Over the past 30 years, considerable worldwide research has been undertaken to quantify the relationship between people's attitudes (annoyance, disturbance, dissatisfaction, bother, etc.) and their daily exposure to noise. In a typical study, people living near a specific, readily identifiable noise source (airport, roadway, railway, etc.) are asked to rate the intensity of their feelings towards the noise produced by that source. When these data are plotted against the respondent's average daily noise exposure, a clear trend of increasing intensity of response with increasing noise dose[2] is shown. The bulk of this research, however, has focussed on a very specific type of noise climate: One characterized by a long history of day-to-day similarity, with only modest daily fluctuations consistent with the type of source involved.

The growth of the air industry, by its very nature, creates perturbations in these otherwise stable noise environments. Some of the perturbations are only temporary; others are permanent. Some result in large changes in noise exposure; others in only small changes. Examples of causal actions include a new airport opening, an old airport being closed, a new runway built to accommodate increased air traffic, a temporary shift in airport operations to accommodate runway repairs, or changes in enroute traffic corridors. In each of these situations, airport neighborhoods undergo rapid, or *abrupt* changes in noise exposure from one level to another, sometimes literally overnight.

An important question to consider when looking to quantify shifts in people's annoyance due to a *change* in exposure is what constitutes a "large" change and what constitutes a "small" one. There

[1] The complete list of the five supplements is: (1) community noise; (2) engine noise reduction; (3) nacelle aeroacoustics; (4) engine/airframe integration; and (5) interior noise.

[2] Such curves are often referred to as "dose-response" relationships.

are two distinctly different ways to approach this question. One is based on the absolute difference in the long term average exposure before the exposure change and after the change. The other is based on the difference in the long term averages compared with the normal day to day variability. More specifically, how many standard deviations of the "before" day-to-day exposure does the average exposure change constitute?

For example, in some airport environments there are significant changes in day to day exposure. This typically happens where there are significant day to day changes in wind conditions (and, therefore runway use). Contemporary signal detection theory holds that it is not the absolute magnitude of the change, but the magnitude of the change compared to normal fluctuations that determines the ease of difficulty in detecting the change in the first place. An example of this phenomenon would be the ability to perceive a 3 to 4 decibel difference in average highway noise levels (where normal fluctuations in exposure are relatively small, such as plus or minus 2 decibels), compared with the ability to perceive the same difference in an airport environment (where day to day fluctuations could be on the order of 5 to 10 decibels). Accepted signal detection theory provides a rigorous framework in which to deal with this issue and *must* be considered in any study design or proposed analysis. Ignoring just this one variable could completely obliterate the chance of finding annoyance changes in either past or future exposure change studies.

For forecasting purposes, the ability to predict the magnitude of an attitude shift under "abrupt-change" conditions is extremely useful. As the first step in a two-step process, existing airport noise simulation models can quantify the expected change in noise exposure. Land use planning studies, environmental assessments and environmental impact statements have employed these tools for many years. The next step, however, predicting the magnitude of the attitudinal shift from the change in noise exposure is currently a far less reliable process in the aircraft/airport environment.

Therefore, the purpose of this study is two-fold:

1) to investigate the current body of knowledge encompassing two related topics:

   - To what extent can we reliably predict the change in people's attitudes in response to an abrupt change in noise exposure, and

   - After the change, is there a decay in the abrupt-change effect whereby people's attitudes slowly shift from their initial reaction to a steady-state value? and

2) provide recommendations for any future work that may be needed.

The literature search located 23 studies relating to one or both of the above topics. All but three studies related to airport or roadway noise sources, and the number of roadway studies was almost twice that of airports. However, most of the roadway studies concerned noise exposure *decreases*, whereas the airport investigations were about evenly split between *increase* and *decrease* conditions.

These prior studies shed considerable light on the current ability to predict initial reaction and decay effects.

One method of predicting the magnitude of an attitudinal change is to use the aircraft noise dose-response curves established from prior studies of populations with stable noise environments. Currently this is probably the best method available. There are several concerns, however, about using this approach. One is whether or not the curves are reliable predictors when the noise change is abrupt rather than gradual. The reason for the concern lies in the findings of a number of roadway noise studies (mostly in Europe) designed specifically to investigate the "abrupt change" phenomenon. Taken as a whole, these studies suggest that people do, in fact, react more intensely to a rapid change than they would to a slow change of the same magnitude. There is considerable scatter in the data, however, and this scatter would have to be resolved to lower the prediction uncertainty to acceptable limits for aircraft use. Additionally, the roadway studies investigated mostly noise *reduction* rather than *increase* situations.

Unfortunately, evidence of a similar nature and extent for airport environments is minimal, and the balance of evidence is inconclusive at best (even though one study included noise exposure changes of ±15 decibels). This state of affairs appears to result from at least three factors: the lesser number of airport studies compared with roadway, the generally less sophisticated approach to experimental design and analysis than found in the more recent roadway studies, and the suggestion by the data themselves that greater noise level changes are needed to observe significant response changes for airport environments than for roadways.

Taken together, however, the literature makes one point very clear: Great care in both experimental design and data analysis is necessary to produce credible, convincing findings, both in the reanalysis of existing data and for planning future data acquisition and analysis studies.

Our recommendation for future work is that additional field studies should be performed, specifically in an airport setting. Before any such studies are planned or implemented, however, it is imperative that four of the previous investigations be reviewed in some detail. These reviews would investigate methodological questions as well as perform alternate analyses of some previously acquired data. For example, to reduce uncertainty in the results of future studies it is desirable to use a panel survey design. In a panel design the same people are interviewed both before and after a noise exposure change. An analysis of two of these data sets could shed considerable light on the extent to which sensitization and/or any other bias effects are introduced using this strategy.

Another two of the previous airport surveys (for which the original data are known to be available) should be reanalyzed using more sophisticated analytical methods and tools. The goal of this reanalysis is to provide more precise information on the probable magnitude of the "airport" abrupt-change effect as a function of noise exposure change. This information would add to the general knowledge base in addition to providing important screening criteria for selecting candidate U.S. airports for further study.

In summary, new airport studies must be designed to minimize nuisance variables and avoid past design features that may have introduced sufficient unexplained variance to mask sought after effects. Additionally, the study must be designed to tie in with previous investigations by incorporating similar survey questions and techniques. Airports of opportunity (those meeting the screening criteria) would be obtained from FAA regional personnel who have knowledge of impending changes at airports under their jurisdiction. No airport is likely to have a complete, ideal set of conditions to resolve all issues. Since a site (airport) bias effect of unknown magnitude is likely to be present, more than one airport may need to be studied.

1. INTRODUCTION

This report is the first in a series of research endeavors to better understand and quantify how people's level of annoyance with aircraft noise responds to a rapid, perceptible change in the average daily noise environment. Such changes are not uncommon as the nation's air transport industry continues to grow.

Over the next few decades the forecast for air industry growth shows a rising trend in numbers of operations. At the same time, federally mandated requirements for a complete transition to quieter aircraft by the year 2000 are resulting in an overall quieter fleet[3]. On this *macro* scale, the national trend towards an overall reduction in aircraft noise exposure is quite comforting.

On a more *micro* scale the continued growth of the air industry creates perturbations in air traffic activity at the local level. These growth-related perturbations include airport expansions (construction of new runways, lengthening of existing runways, new operational procedures to optimize use of existing airspace, etc.), construction of new airports, and restructuring of enroute airways between cities. With each of these actions comes changes in local noise environments. Some communities experience increases while others experience decreases. Many of these changes literally take place overnight.

The bulk of the available information for relating people's attitudes to their degree of noise exposure comes primarily from studies of slow-change or no-change situations rather than abrupt-change noise environments. The question from a human response perspective is whether or not the degree to which attitudes change is the same for an abrupt-change as it would be for a slow-change of the same magnitude. Roadway studies of this issue (conducted mostly in Europe) tend to indicate that people *do* react differently. There is a greater shift in annoyance for the abrupt-change situation than there is for a slow-change. Similar studies for airport noise environments are fewer in number and have provided generally inconclusive results. Hence, there is considerable interest in resolving the slow-change / abrupt-change issue in aircraft noise environments.

1.1 Background

Over the past 30 years, considerable worldwide research has been undertaken to quantify the relationship between people's attitudes (annoyance, disturbance, dissatisfaction, bother, etc.) and their daily exposure to noise. In a typical study, individuals living near a specific, readily identifiable noise source (airport, roadway, railway, etc.) are asked to rate the intensity of their feelings towards that source. When these data are plotted against the individual's average daily noise exposure, a clear trend of increasing intensity of response with increasing noise dose is evident.

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[3] Once the transition is complete, however, the national aircraft noise climate will go on the rise again unless new (lower) noise standards are set for new production aircraft.

Unfortunately, the results of these individual studies have not been easy to compare. Each was done relatively independently of others, mostly due to differing objectives, availability of resources, and research techniques. A further complication has been the lack of any standardization in attitudinal scales or noise metrics. Each country or research establishment had their own standards, or researchers were working at a point in time when there was a flurry of activity to find particular dose and response indices that best correlated with one another.

Almost twenty years ago, Schultz (1978) published his landmark synthesis of relevant community noise dose-response information. While many assumptions had to be made regarding the comparability of attitude scales, and translation factors had to be estimated between noise metrics, Schultz illustrated that much of the data did in fact cluster and suggested a dose-response relationship to which he mathematically fit a third-order curve.

More recently Fidell, et al (1991) extended Schultz' original work by incorporating data from additional studies conducted since the original 1978 publication. For the most part, the additional studies confirmed and added strength to Schultz' original work. In addition however, Fidell also demonstrated the presence of a "site" effect. He suggested that the general functional form relating annoyance to average daily noise level was approximately the same for any particular site (airport, roadway, etc.). However, to achieve a tight clustering of the data from all studies, the data sets from the individual sites had to be translated along the noise level axis by some unique, site-specific amount. Essentially Fidell implied that (to a first approximation) most communities exhibit the same growth in annoyance for a given change in noise level, but that communities have different sensitivities, or "affective states" (Fidell, et al, 1988) that can be directly translated into a decibel equivalent on the noise level axis.

The common thread between all of these studies is the noise-stable environments in which the data were collected. That is, the respondents who participated had a noise exposure pre-history characterized by minor day-to-day fluctuations, devoid of any major shifts in noise dose.

In 1992 the Federal Inter-agency Committee on Noise (FICON) published its findings in the report "Federal Agency Review of Selected Airport Noise Analysis Issues." In this report FICON identified near term research goals to fill critical gaps of knowledge. One of those goals was to better understand the relationship between annoyance and an abrupt-change in noise exposure.

At much the same time, Fields (1992) was completing a synthesis report on the effect of personal and situational variables on noise annoyance. Fields investigated the literature for a number of topics: Two of these are the main focus of this study, and he couched them in the form of hypotheses:

Topic 20) *People overreact to changes in noise levels (either increase or decrease), and*

Topic 21) *With time, annoyance with a new noise source decreases.*

Fields reported the evidence to be mixed as to whether residents overreact to change (Topic 20). For present purposes, overreaction is defined as a statistically significant departure from a "baseline" dose-response relationship. The baseline relationship has been established from respondents whose neighborhoods had been long exposed to the same general level of noise exposure, day after day (just like the data underlying the Schultz relationship). The curve shown in Figure 1-1 illustrates such a relationship. The curve has been used to estimate (with some uncertainty limitations) the degree of annoyance in a population long-exposed to sound level X, or another population long-exposed to sound level Y. In most previous studies, the difference between X and Y is a spatially-dependent one; that is, one in which the exposure difference between X and Y, and any difference in response is determined from two, geographically separated neighborhoods.

The central question in the case of a rapid change in noise exposure from X to Y is whether or not the baseline curve may still be used to estimate a *temporal* change in annoyance, one in which the change from X to Y occurs within the same neighborhood due to some change in airport, highway, etc. operations. If not, is there an over- or under-reaction such as the one illustrated in Figure 1.1. Either of the two conditions shown (and determined to be significantly different in exposure and annoyance response from the baseline) would suggest that space and time are *not* interchangeable.

Fields' analysis clearly shows that residents *do* react to a change, but whether or not it is an overreaction is unclear. Furthermore, he conversely states that there may be an under-reaction phenomenon at work as well. The extreme of the under-reaction case is when a physically measurable exposure change does in fact take place, the survey respondents cannot detect it, and they report no attitudinal shift whatsoever.

Fields also reported that the evidence was mixed on whether or not annoyance with a new source decreases with time (Topic 21). He correctly identified the major problem with most of the existing data: Too long a time had elapsed before the communities were first surveyed after the change. If the hypothesis is correct, but most of the annoyance decrease occurs in the first few weeks or months, then most of the existing studies would have missed the period of major decrease altogether. For present purposes we include two situations under Topic 21, (1) the addition of a new noise source which was not previously noticeable, and (2) a large change in sound exposure for an existing source.

Fields summarized by stating that to learn more and resolve both of the issues, further work needed to be done. He suggested that the mixed evidence might not necessarily reside in the basic data, but in the differing ways in which it was analyzed and presented for publication. He recommended a two-step approach. First, find as many candidate available data sets as possible and perform parallel analyses on them using modern statistical techniques. Anticipating that this undertaking may not resolve all of the crucial issues, he states:

> *... it is likely that further, more methodologically sophisticated original research would be required to make substantial progress on these ... topics.*

Beginning in October of 1993, The National Aeronautics and Space Administration (NASA), in cooperation with the Federal Aviation Administration (FAA) and industry partners, launched the Aircraft Noise Reduction (ANR) Program. Looking toward the twenty-first century and the forecasts for growth in the commercial aviation industry, the program goal is to apply all possible technology towards improving the capacity of the nation's airport and airways systems, while at the same time reducing environmental impact. To this end, the AST program includes a wide range of sub-elements, including (1) evaluation of high-lift aerodynamic systems to reduce airframe noise and examination of possible noise-generating engine/wing interactions, (2) development and validation of interior noise reduction methods for quieting both cockpit and cabin, and (3) reduction of community noise impact through the application of new airplane technologies and operating procedures, enhanced accuracy of aircraft/airport noise prediction models, and a better understanding of human response to aircraft noise exposure variables. The tasks focusing on the improved understanding of human reaction encompass the current study.

1.2 Purpose of the Project

There are three basic objectives of this project. The first is to identify long range goals related to people's reactions to *changes* in noise exposure. Of particular interest are those exposure change scenarios that are likely to arise from airport and airway capacity enhancing actions. The second objective is to identify and acquire the knowledge base regarding the above two topics. From this literature, items sought include methodological strengths and weaknesses, trends in substantiated

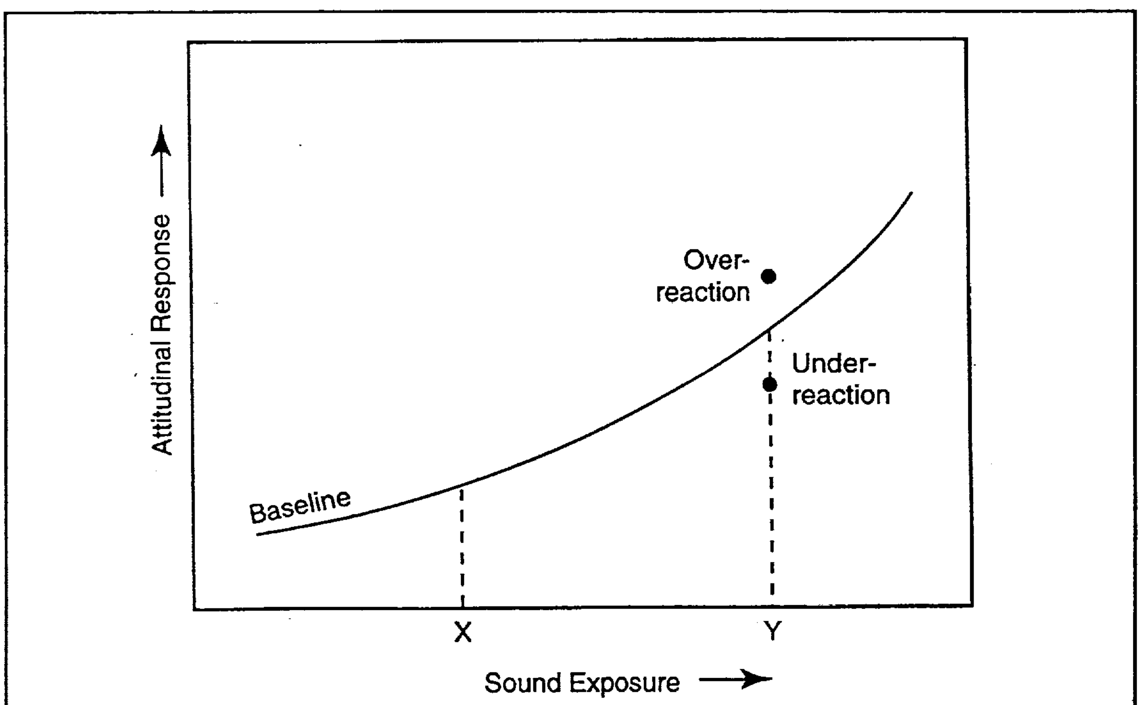

Figure 1-1. Typical Baseline Dose-Response Relationship

findings, and promising data sets for more sophisticated reanalyses. Given the results of the first two objectives, the third is to recommend a course of action for achieving the stated goals. This undertaking includes identifying the basics of a modern data acquisition and analysis program. It also includes specifying past data sets for reanalysis using the suggested analysis methods. These reanalyses would be designed to ferret out methodological strengths and weaknesses as well as to look for supporting or conflicting evidence for the two hypotheses.

1.3 Problem Definition

The current project began in the Summer of 1994 with a start up meeting attended by representatives of the National Aeronautics and Space Administration (NASA), the Federal Aviation Administration (FAA), the Armstrong Laboratories of the United States Air Force (USAF), the Army Environmental Hygiene Agency, Lockheed Aeronautical Systems Company, and members of the HMMH staff representing aircraft, highway and rail noise disciplines. The purpose of the meeting was to clarify project goals and set a focused direction for the remainder of the project, thereby providing a framework for the literature review.

The FAA reported that it is nearing completion of the newest release of the Integrated Noise Model, INM 5.0. In addition to its traditional capability of preparing noise contour sets for individual airport operating scenarios, the new release will be capable of calculating *difference* contours between scenarios. Given this capability, the next logical step is to provide an ability to translate the magnitude of the change into an impact assessment.

Putting bounds on the problem, consistent with the air capacity issue driving this program, there was general agreement on the following points:

- Aviation noise is the focus of the current study,
- Only residential neighborhood exposure will be considered,
- High exposure levels are just as important as low exposure levels,
- Long term changes are more important than short term changes,
- Exposure increases are more important than decreases,
- Annoyance and complaints are both important,
- Investigating community group reactions or health effects is *not* a part of this study.

1.4 Report Organization

At the completion of the literature search, 57 references to 23 relevant studies were located. Section 2 of this report provides an overview of what was found, and includes discussions of the study settings and the types of noise sources investigated. It also discusses the various dimensions to a noise exposure change, and reports the dimensional characteristics for each of the studies.

In order to set a general framework for thinking about independent and dependent variables a very generalized model of human response to a change in noise exposure was developed. The model and variables are discussed in Section 3.

Section 4 examines the various study designs found in the literature and identifies a basic approach for examining the magnitude of a change in exposure effect.

A number of different dose metrics were used in the studies, as were a number of methods for determining respondent doses. These issues are discussed in Section 5.

A key element in the design of any study is the consideration of potential mediating and confounding variables. These are identified and discussed in Section 6.

Section 7 identifies the various means by which responses were determined and provides the text for the noise annoyance question for each survey.

Section 8 discusses the analysis methods used in the prior studies, as well as the meta-analysis method used by Fields in his recent analysis of personal and situational variables.

Section 9 provides an overview of the findings and conclusions from this investigation. Section 10 provides a fairly detailed overview of recommendations for further research.

A complete list of references and a glossary of terms follow Section 10. The appendices follow the glossary.

2. OVERVIEW OF THE AVAILABLE LITERATURE

2.1 Broad Overview

Information on 23 studies of human response to changes in noise exposure were located in 57 citations during the course of this investigation. The earliest study dates back to 1961; the most recent was completed in 1992, a span of over 30 years. A brief synopsis of each study, its list of references, and its catalog number (described later in this section) is provided in Appendix A.

Since the first of these studies was undertaken, significant changes and advances have occurred on many fronts. For example, the noise sources themselves have undergone change. Airline fleets have progressed from the end of the piston engine era through several stages of turbine engine development. Flight volumes have increased considerably as demand for air travel has expanded worldwide. Highway noise emissions have been somewhat controlled by Environmental Protection Agency (EPA) truck noise emissions standards developed during the late 1970's and early 1980's. Noise barriers protecting residents from nearby roadways have emerged as an accepted mitigation strategy.

At the same time, technology has advanced dramatically in the capabilities of noise measurement instrumentation, the sophistication of noise prediction models, and the standardization of noise metrics. Precision, versatility and consistency have increased while cost has decreased. For example, continuous noise monitoring was a very expensive proposition during the early 1960's, and was mostly limited to a very few airports with permanent noise monitor systems. Temporary, 24-hour monitoring was both tedious and labor-intensive, and these two factors generally discouraged the acquisition of long data samples of days or weeks needed to obtain stable, long-term average values of noise exposure.

Noise level prediction models have evolved from pencil and workbook technology to sophisticated computer-based models with detailed aircraft noise and performance databases. Twenty-five years ago, the airport-specific data parameters (runway use, fleet mix, etc.) needed for these models was rarely, if ever, routinely maintained by any airport and estimates by airport personnel were often the only source of information. Now, within the past five to ten years, increasingly accurate methods for acquiring these input data to the models have evolved.

Advances have occurred in social survey design, execution and analysis, as well. Similarly, statistical analysis techniques and procedures have improved. An analysis requiring mainframe computing power twenty-five years ago can now be done faster and cheaper right at the desktop. Combined with improvements in inferential statistics, the researcher can now probe his or her data set faster and in more ways than ever before possible.

For the above reasons, the body of available literature was expected to cover a great range in study designs, data acquisition and analysis techniques, and a wide range of evolving methodologies and technologies. What is readily possible today would never have been considered 30 years ago. Thus, it is reasonable to expect a considerable range of sophistication in the techniques employed in the reviewed literature.

2.1.1 Study Settings

All 23 of the studies were conducted in either the United States, Europe, Australia, or Japan. In each study, a residential community (or series of communities) experienced a change in noise exposure due to a change in some attribute of a particular noise source (referred to hereafter as the *target* noise source or a change in the propagation path between the source and receiver). In all but one of the cases, the source was transportation related.

All of the studies were conducted in a field setting. That is, people were interviewed in their own homes, and their opinions were sought concerning noise sources with which they had daily experience in their home. Studies conducted in a laboratory setting were neither sought nor considered in this investigation.

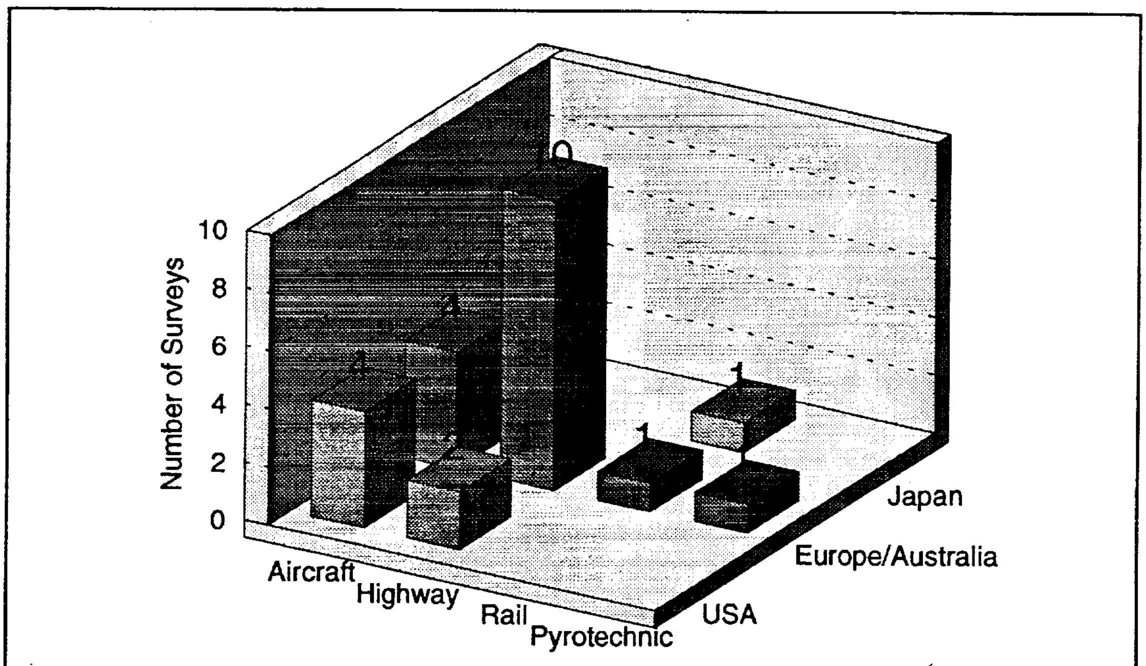

Figure 2-1. Distribution of Studies by Noise Source and Region of Origin

Figure 2.1 presents an overview of the numbers of studies by region and noise source. Two features of this graph stand out. First, two-thirds of all the studies were conducted in Europe and Australia (mostly Europe), and all but one of the remainder were conducted in the United States[4]. Second, there were more roadway studies than all other noise sources combined[5]. In fact, the figure strongly suggests the bulk of all work relates to European roadways. From this, one could speculate that a good deal of the serious thinking on the change in exposure topic might be found in these European roadway studies. This supposition does, in fact, turn out to be the case as will be seen later in this report.

The pyrotechnic study stands out as unique in its target noise source. This study employed explosive detonations from tethered balloons to simulate sonic booms in a southern English village. These detonations are impulsive in nature, and such noise signatures have been shown to have a rise-time related startle factor associated with them (Plotkin & Bradley, 1992 and Stusnick and Plotkin, 1992). Therefore this study is considered of limited usefulness in the current investigation.

2.1.2 Information Sources and Information Management

The information collected during this investigation was obtained from a variety of sources. For the most part, refereed professional journals, government documents, and contractor reports provided the bulk of the information[6]. Personal communications with principal investigators provided the balance.

Frequently, more than one citation was found for a single study. For example, a contractor report for a government agency might have been followed by a professional journal article by the same author. The articles often provided additional insight to the results of the study. Multiple journal citations were also found. Sometimes an original report or article was followed by one or more synthesis articles comparing the results of the study of interest with the results of other studies. In one case, an initial publication drew the interest of a different investigator who offered alternative analyses and conclusions from the original author, who in turn offered a reply.

For information management purposes, each study received a catalog number. The catalog numbering system, first advanced in an earlier survey synthesis report (Fields, 1991), uses a six character identifier (three alphabetic followed by three numeric). The alphabetic characters identify the country where the study was conducted (eg. GER = Germany, UKD = United Kingdom, etc.). They are included for informational purposes only; they are not part of the cataloging system. The three numeric characters form a three digit number which is chronologically assigned as new studies enter the catalog system.

[4] Final tally: 14 in Europe, 2 in Australia, 6 in the U.S. and 1 in Japan.

[5] Final tally: 12 roadway, 8 airport, 2 railway, and 1 pyrotechnic.

[6] HMMH is indebted to Mr. Jim Fields who made available a large portion of the documents from his personal library.

2.2 List of Studies Found

The studies divide into three basic target source categories, airport, roadway, and rail. A brief description and listing of each study is provided in the three sub-sections below. Figure 2-2 provides a chronological perspective by plotting each study's start and duration against a common time line. The first airport study began in 1961 and the first roadway study in 1963. The first rail study was performed in 1973.

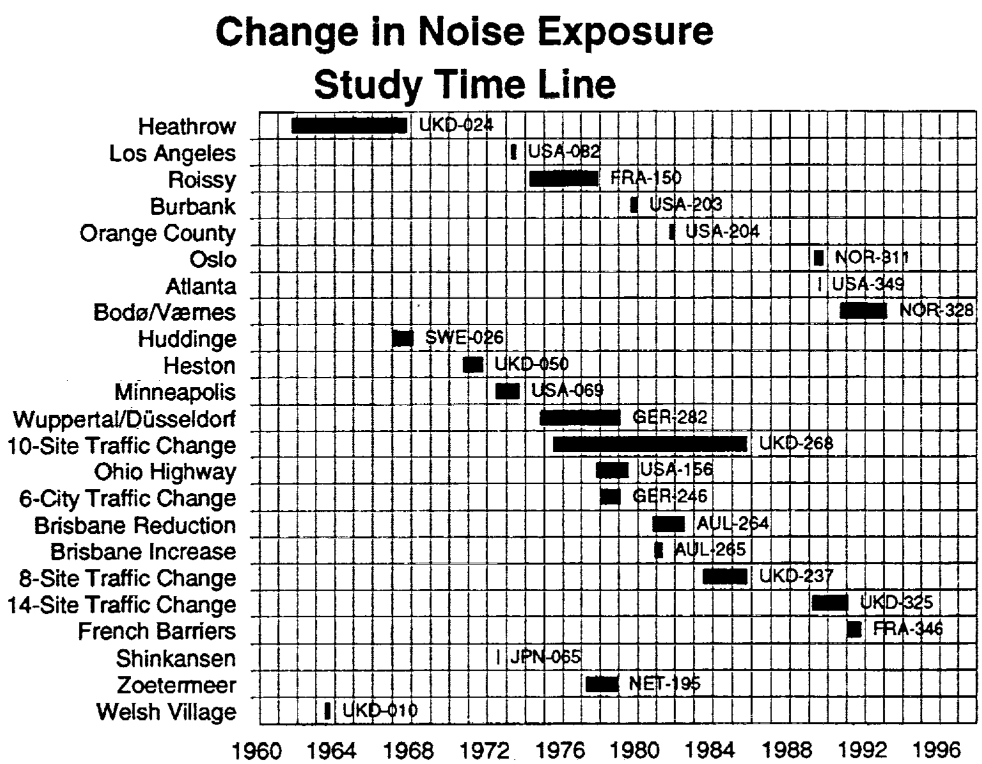

Figure 2-2. Chronology of Change in Noise Exposure Studies

2.2.1 Airport Studies

The eight airport studies reviewed in this investigation were conducted between 1961 and 1992. The combined research encompasses four different countries on two continents. Table 2-1 provides an overview of the studies by identifying the airport, when the study was conducted, and the study catalog number. Appendix A, Section 1 provides a brief description of each airport study.

Table 2-1. Overview of Airport Studies

Study	Location	Survey Date(s)	Code
Heathrow Evolutionary Air Traffic Change	London (Heathrow) Airport *(London, UK)*	1961, 1967	UKD-024
Los Angeles Permanent Night Flight Cessation	Los Angeles International Airport *(Los Angeles, CA, USA)*	1973	USA-082
Roissy New Airport Opening	Paris (Charles de Gaulle) Airport *(Roissy, France)*	1974, 1975, 1977	FRA-150
Burbank Temporary Runway Closure	Burbank-Glendale-Pasadena Airport *(Burbank, CA, USA)*	1979, 1981	USA-203
Orange County Temporary Departure Procedure Changes	John Wayne (Orange County) Airport *(Santa Ana, CA, USA)*	1981	USA-204
Oslo Temporary Traffic Increase	Oslo (Fornebu) Airport *(Oslo, Norway)*	1989	NOR-311
Atlanta Permanent Noise Insulation	Hartsfield-Atlanta International Airport *(Atlanta, GA, USA)*	1989	USA-349
Bodø/Værnes Temporary Military Exercises	Bodø and Trondheim (Værnes) Airports *(Bodø and Trondheim, Norway)*	1990, 1991, 1992, 1993	NOR-328

2.2.2 Roadway Studies

Thirteen roadway studies were conducted between 1967 and 1991. Table 2-2 lists these studies. The majority were from Europe (Scandinavia, the United Kingdom, France and Germany) with the remainder coming from the United States and Australia. Appendix A, Section 2 provides a description of each roadway study.

Table 2-2. Overview of Roadway Studies

Study	Location	Survey Date(s)	Code
Huddinge New Highway Opening	New Highway *(Huddinge, Sweden)*	1967, 1968	SWE-026
Heston Noise Barrier Construction	M4 Motorway *(Heston, UK)*	1970, 1971	UKD-050
Minneapolis Noise Barrier Construction	Interstate 35W *(Minneapolis, MN, USA)*	1972, 1973	USA-069
Wuppertal/Düsseldorf Noise Barrier Construction	7 Areas Near Autobahns A46 and A59 *(Wuppertal and Düsseldorf, Germany)*	1974-1975, 1979	GER-282
10-Site Traffic Change	10 Areas Affected by Traffic Flow Changes *(Boughton, Bridge, E. Grinstead, Leeds, Lewes, Ludlow, Mere, Stafford, and Tring, UK)*	1975-1978, 1985	UKD-268
Ohio Highway New Highway Opening	New Interstate Highway Connection *(Ohio, USA)*	1977, 1978, 1979	USA-156
6-City Traffic Change Traffic Reduction Measures	50 Areas Affected by Traffic Flow Changes *(Düsseldorf, Essen-Frohnhausen, Gelsenkirchen-Schalke, Köln, Münster, and Oberhausen, West Germany)*	1978-1979 (?)	GER-246
Brisbane Reduction Traffic Reduction from Nearby Freeway Opening	Residential Street *(Brisbane, Australia)*	1980-1981	AUL-264
Brisbane Increase Traffic Increase from Through Street Construction	Residential Street *(Brisbane, Australia)*	1980, 1981, 1982	AUL-265
8-Site Traffic Change	8 Areas Affected by Traffic Flow Changes *(Alderney, Bedfordshire, Essex, Kent, Suffolk, and Surrey, UK)*	1983-1984, 1985-1986	UKD-237
14-Site Traffic Change	14 Areas Affected by Traffic Flow Changes *(UK)*	1989-1991	UKD-325
French Barriers Noise Barrier Construction	2 Areas Near Motorways *(France)*	1991	FRA-346

2.2.3 Railway Studies

Only two railway studies were conducted, one in Japan and one in The Netherlands. These are identified in Table 2-3. Appendix A, Section 3 provides a summary description each of these studies.

Table 2-3. Overview of Rail Studies

Study	Location	Survey Date(s)	Code
Shinkansen New High Speed Rail Line Opening	Tokaido and Sanyo Express Lines *(Akashi, Kyoto, Shimizu, and Shiznoka, Japan)*	1972	JPN-065
Zoetermeer New Commuter Rail Line Opening	Sprinter Commuter Rail Line *(Zoetermeer, The Netherlands)*	1977, 1978	NET-195

Only one additional study (which fell into neither the airport, roadway, or rail groups) was found. In this study, pyrotechnic devices were detonated at random times of the day and night near a town in southern England. This study sought to learn more about peoples' reactions to sonic booms.

2.3 Dimensions of Noise Exposure Change

In general, the Day-Night Average Sound Level (DNL) or some other multi-hour measure of daily noise exposure was used to quantify noise dose in all of the studies. Few studies went beyond the level of a composite daily measure by attempting to isolate individual components of a 24-hour metric (such as the magnitude of individual noise events, numbers of events, time-of-day, etc.) and drawing inferences about their separate causal effects on attitudes. Some studies, however, investigated more than one noise measure to determine whether one was a better predictor of annoyance than another.

The noise exposure changes found in this investigation had five basic dimensions: (1) the character of the change (higher or lower than previous exposure), (2) the magnitude of the change, (3) the rate at which the change occurred, (4) the duration of the change, and (5) the mechanism causing the change. Table 2-4 summarizes these dimensions and provides examples of each.

Table 2-4. Dimensions of Change in Noise Exposure

Dimension	Category	Example
Characteristic of Change	Introduction of new target source.	Opening of new airport or highway.
	Complete removal of target source.	*None were found in this review.*
	Increased exposure from pre-existing target source.	New airport runway opening.
	Decreased exposure from pre-existing target source.	Installation of highway noise barrier.
Magnitude of Change	Continuous scale from large negative change, through no change, to large positive change.	-15 dB, +1 dB, +17 dB
Rate of Change	Gradual	Gradual change in airport operations over several years.
	Abrupt	Opening of new roadway, or new rail line.
Duration of Change	Temporary	Runway closure for repairs.
	Permanent	Opening of a new runway.
Mechanism of Change	Source	Reduction in roadway traffic volume.
	Propagation path	Roadway barrier; residential noise insulation.

2.4 Phases of Noise Exposure Change

Chronologically there are three phases to an exposure change, (1) the *before* period leading up to the change, (2) the period *during* the change itself, and (3) the *after* period, subsequent to the change. The concept is illustrated in Figure 2.3 which plots daily sound exposure as a function of time. The top half of the figure is a stylized illustration of the process, devoid of any day-to-day variability. The lower half presents a somewhat more realistic view by introducing day-to-day exposure variability to the process. Placing the magnitudes of normal daily variations and abrupt exposure change in perspective with one another suggests the potential importance of day-to-day variance in the annoyance prediction equation.

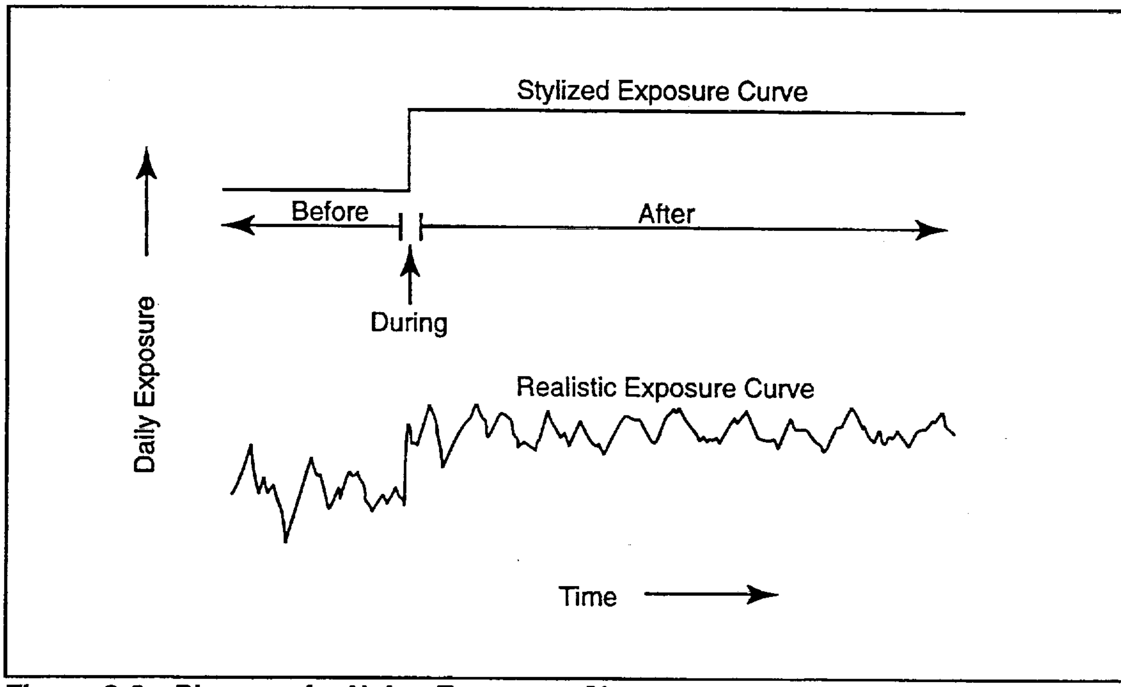

Figure 2-3. Phases of a Noise Exposure Change

During the *before* phase, residents generally have a long prehistory (a year or more) of a stable, predictable noise environment. Other than normal day-to-day fluctuations (and perhaps seasonal variations as well), the average exposure remains relatively constant. For the case of a new source being introduced, this phase is characterized by the normal ambient noise environment.

During the *change* phase, some aspect of the noise source or the propagation path is altered, resulting in a change in the residential noise environment. The change may literally occur overnight, as in the opening of a new airport runway; or it may also evolve over time, as older, noisier aircraft are replaced by newer, less noisy models. It has been postulated that in the former case, the abruptness of the change may uniquely affect people's attitudes about the new noise exposure. That is, the degree of annoyance after an abrupt change is not the same as that after a slow, evolutionary change, even though the magnitude is the same in both cases.

During the *after* phase, the noise exposure becomes stable and predictable once again, but at a new average level. It is postulated that during this phase (if the change was rapid) that there may be some decay over time in any abrupt-change effect.

2.5 Phases of Community Attitude Change

Prior to the change, community attitudes remain fairly stable. Immediately following the change, however, residents may express an over or under reaction in their attitudes to the new noise environment. A schematic chronology is shown in Figure 2-4. The baseline (shown as a horizontal dashed line) is used as a criterion for *over* or *under*, is ideally derived from the attitudes of nearby residents with a long pre-history of the same noise exposure that the "changed" community receives after the change. No notions of how long the initial reaction may persist has been advanced, but one study (Fidell, 1981) suggests it may not be more than a few days or weeks.

After the initial reaction there is the question of whether adaptation occurs. That is, do residents' attitudes slowly shift with time? How far they shift, or even if they shift at all, is a critical question to be answered. There is some belief that over time, perhaps months or a year later, attitudes will shift to a value that is commensurate with a community with a long pre-history of the same exposure. Another assertion is that no adaptation ever takes place (or if it does it takes many years), and whatever the initial reaction, attitudes hold steady and simply stay that way.

Table 2-5 summarizes the characteristics of each study for the five foregoing dimensions. The first column of the table identifies the study. The next three columns identify the characteristics of the change that were investigated, a newly introduced target source, an increase in an existing target noise level, or a decrease in an existing target noise level. The next column shows the size of the noise level change. When a single number is cited, all respondents in the study experienced about the same change. When two numbers are shown, the change varied across respondents and the range of changes is tabulated.

The next two columns identify the rate of change from the original noise environment to the new one. The Abrupt category includes both overnight changes (such as the opening of a new runway) as well as those of a few weeks (such as the construction of a roadway noise barrier). The Gradual category identifies a slow evolutionary process, such as the growth in air traffic over a period of several years.

The next two columns identify whether the noise change was temporary (a few weeks or months) or permanent. The mechanism by which the change occurred is shown in the next two columns. Either some element of the source or some element of the propagation path was the cause. The last two columns indicate which phases of the change were studied, the change itself or a possible adaptation following the change.

2.6 General Observations

With regard to the two attitudinal response effects of interest, (1) the abrupt-change effect to a rapid exposure change, and (2) the decay of such an effect, the research findings are mixed. One statement may be made with confidence: If either effect truly exists, especially in an airport setting, it may be relatively small in relation to the magnitude of the change. Effects *were* found in some roadway studies and some were large, but whether they can be observed in the data of prior airport studies is

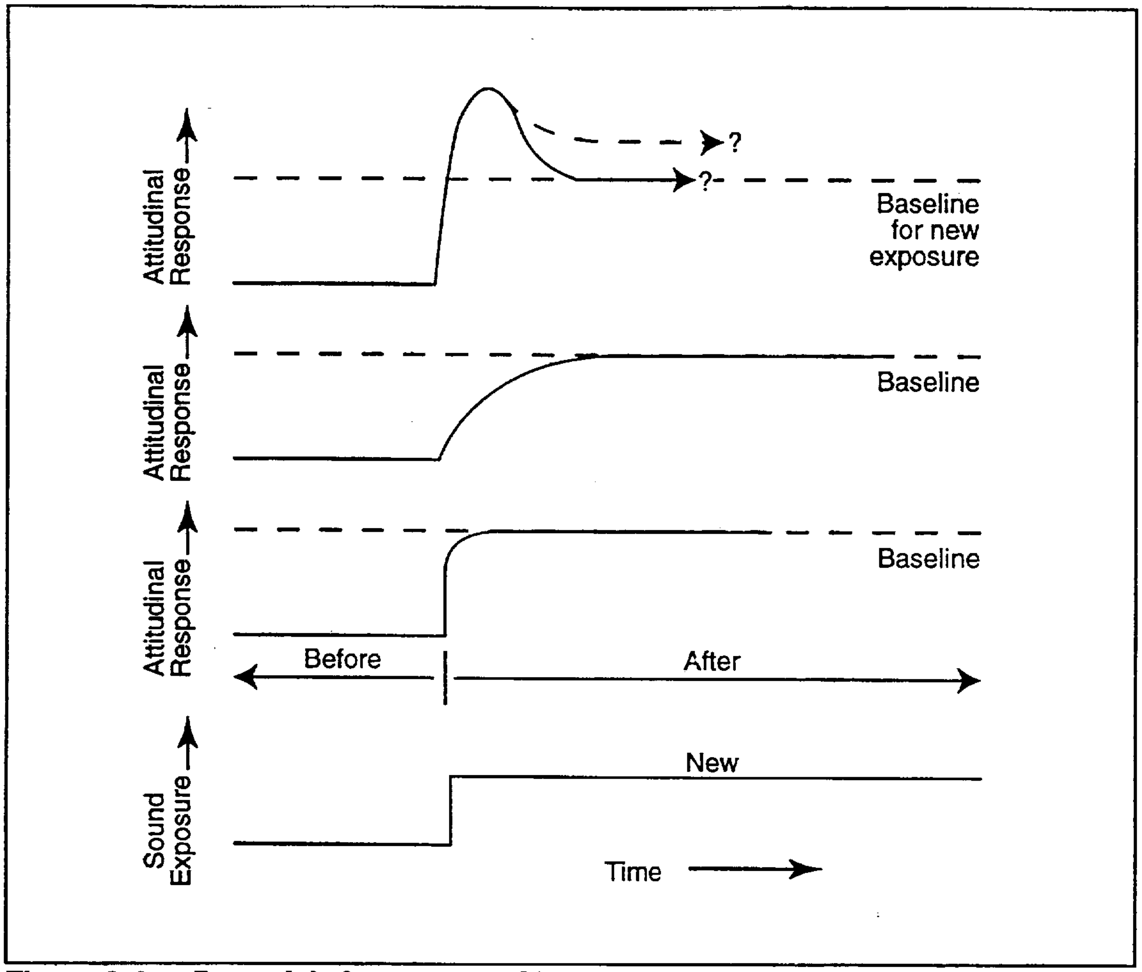

Figure 2-4. Potential Annoyance Chronologies Resulting from Rapid Noise Exposure Increase

still questionable. In follow-up field studies, it is extremely important to find neighborhoods where expected exposure changes (as measured by a 24-hour Leq or Day/Night Average Sound Level) are 10 decibels or more. Hopefully, this will ensure that at least *some* evidence of the effect (if there is any) may be observed. Conversely, airports where maximum exposure changes of only 5 decibels are expected should be treated as marginal in terms of providing any fruitful results whatsoever.

A partial explanation of this outcome may lie in the near continuous character of roadway noise, compared with the intermittent character of aircraft noise. In the case of a continuous source, there is far less moment-to-moment sound level variability than there is with an intermittent source, like airplanes and trains. Given this simple difference, an argument could be made from psychophysical signal detection theory (Green and Swetts, 1966) that the same change in average sound exposure would be far easier to detect with a near continuous (roadway) noise source than with an intermittent (aircraft) source. Stated another way, larger changes than those investigated for highway noise studies may be needed to achieve similar changes in response.

Table 2-5. Noise Exposure Change Attribute Summary

Name of Study	Characteristic of Change				Rate of Change		Duration of Change		Mechanism of Change		Phase of Change Investigated	
	New	Incr.	Decr.	Size (dB)	Abrupt	Gradual	Temporary	Permanent	Source	Prop. Path	Change	Adaptation
Airport												
Heathrow		✓		3		✓		✓	✓		✓	
Los Angeles			✓	-3	✓			✓	✓		✓	
Roissy	✓			DK	✓			✓	✓		✓	✓
Burbank		✓	✓	-17, +9	✓		✓		✓		✓	✓
Orange County		✓	✓	-2, +2	✓		✓		✓		✓	
Oslo		✓		+3, +10	✓		✓		✓		✓	
Atlanta			✓	-5	✓			✓		✓	✓	
Bodø/Værnes		✓		+3, +15	✓		✓		✓		✓	
Roadway												
Huddinge	✓			DK	✓			✓	✓			✓
Heston			✓	-6, -1	✓			✓		✓	✓	
Minneapolis			✓	-6, -4	✓			✓		✓	✓	
Wuppertal/Düss			✓	-18, -3	✓			✓		✓	✓	
10-Site Traffic			✓	-16, -3	✓			✓	✓		✓	✓
Ohio Highway	✓			DK	✓			✓	✓			✓
6-City Traffic		✓	✓	-3, +4	✓			✓	✓		✓	
Brisbane Red.			✓	-15	✓			✓	✓		✓	
Brisbane Incr.		✓		8	✓			✓	✓		✓	✓
8-Site Traffic		✓	✓	-15, +15	✓			✓	✓		✓	✓
14-Site Traffic		✓	✓	-10, +5	✓			✓	✓		✓	
French Barrier			✓	-10, -3	✓			✓		✓	✓	
Railway												
Shinkansen	✓			DK	✓			✓	✓		✓	✓
Zoetermeer	✓			DK	✓			✓	✓			✓

Therefore extreme care must be taken in future research to minimize unexplained variance, to avoid potentially confounding variables, and to obtain adequate sample sizes so that error bounds on numerical results are commensurately smaller than the size of the effects being sought. This is a major hurdle that *must* be overcome in future study designs.

3. A GENERAL MODEL OF HUMAN RESPONSE TO A CHANGE IN NOISE EXPOSURE

Before reviewing the literature in detail, it is useful to establish a perspective on the dose-response process, and to hypothesize a general model for human response to changes in noise exposure. The specific change scenario under discussion is one in which a single target noise source (such as aircraft) is either (1) newly introduced to the environment, or (2) is pre-existing and some aspect of the target noise changes. At its most elementary level, such a model has three components: Sensory inputs, the human processor, and response outputs. The particular output responses of interest in this investigation are attitudinal (as opposed to behavioral). In keeping with a large body of the literature the attitudinal variable may be generalized as "annoyance", "dissatisfaction", "bother" etc. and the measurement scale is intensity of feeling, quantified by a scale of adjectives expressing greater and greater severity.

Figure 3-1 shows the model for a human being in schematic form. The inputs are grouped into two categories: (1) objective variables that can be measured, and (2) mediating, situational variables which combine in some fashion with each other and/or the target source variables to determine the response. The manner in which combining takes place will be unique to each individual, and will form that person's response. Other variables which are not easily quantified (such as the respondent's mood, health, predisposition toward the source in general, etc.) enter the equation as well and emerge from the process as unexplained variance from a collection of responses.

Candidate target source variables shown in the figure include the starting environment (whether or not the target source is already present in some degree, the average and standard deviations of the starting DNL before the change and the ending DNL after the change, the elapsed time since the change occurred, and the speed with which the change took place (overnight, within a few days, over a period of several weeks, etc.).

Candidate mediating variables include the season of the year (surrogate for windows open/closed, for annual, cyclical air traffic changes, etc.), the mechanism causing the change (something about the source itself, or something about the propagation path, or both), the respondent's location relative to flight corridor centerlines (possible surrogate for fear of crash), preknowledge of the change, duration of the change (if temporary), the perceived concern of public officials about the noise consequences of the change, the importance of the outdoors to the at-home lifestyle, and general attitudes about various aspects of the community, and a categorical variable, the specific airport itself.

At this point in time it would seem premature to become more detailed or speculative in the internal structure of the model. To do so would impose that structure on the data analysis and might result in greater unexplained variance than letting the data itself tell the story with a little help from the data analyst. By examining the correlations between independent variables, especially in the light of potential causality, alternative cause/effect relationships can be hypothesized. Each hypothesis will lead to a specific prioritization of the order in which the variables (and their interaction terms) enter the regression analysis. This issue is discussed at greater length in Section 10 of the report.

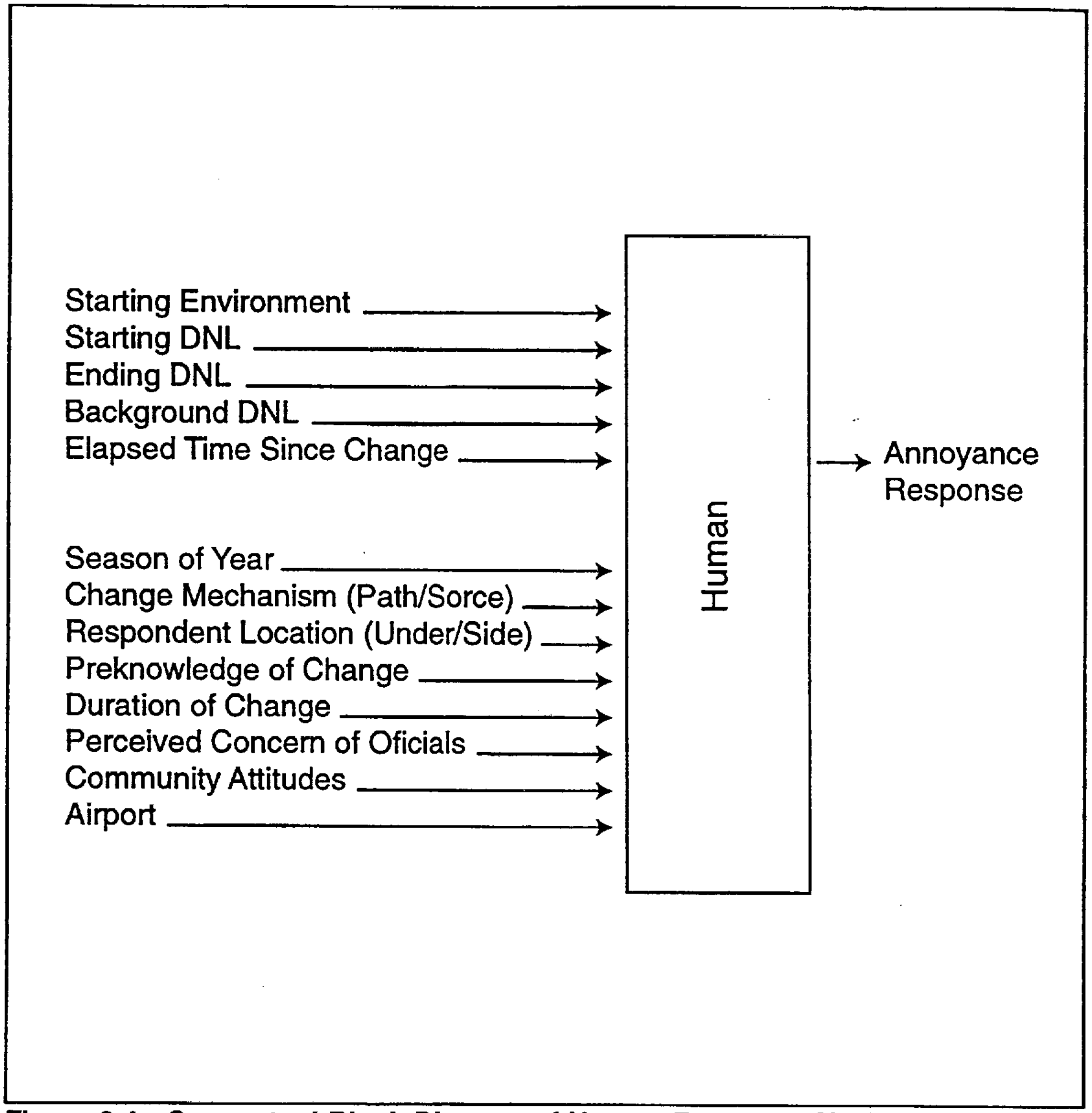

Figure 3-1. Conceptual Block Diagram of Human Response Model

The response outputs from all respondents would be analyzed in two ways, the mean response, and the percent highly annoyed. The mean response has the greatest statistical power because it accounts for the entire distribution of individual responses. This variable is strongly embraced for searching out the potentially small effect in an airport setting. The percent highly annoyed has historical significance as well interpretability to the lay public. As discussed in Section 10, any finding in mean annoyance can be translated to a centile annoyance scale.

4. STUDY DESIGNS

All of the studies reviewed in this document were undertaken, at least in part, to measure attitudinal responses to a change in community noise exposure, or to track attitudes over a period of time following the change. These studies lead to conclusions about cause and effect relationships between a change in noise exposure and a change in attitudes concerning noise. However, beyond this common thread there lie numerous differences between the studies, their designs, and their results. Understanding the similarities and differences between the studies requires examining (1) the distinctions between the goals of the studies, (2) the distinction between longitudinal and cross-sectional study designs, (3) the timing of interviews relative to the noise exposure changes, and (4) the study populations. These issues are discussed in the following sub-sections.

4.1 Goals of Change in Noise Exposure Studies

The studies in this review had two general goals:

- to measure the difference in community attitudes before and after a change in exposure, and/or

- to measure how community attitudes change over a period of constant noise exposure following a change.

A critical issue in the studies that examine community attitudes before and after a change is the magnitude of the change effect; except for the Heathrow study, the noise exposure changes were abrupt. On the other hand, in the studies that examine the change in attitudes following a change, the issue is the degree to which there may be a decay in the change effect; these studies do not necessarily involve any measurements before the change.

4.1.1 Examining Attitudinal Changes to the Noise Exposure Change

The design of the Los Angeles study is typical of studies designed to measure the change in attitudes before and after a noise exposure change. The study included 3 rounds of interviews in 3 clusters of residences near Los Angeles International Airport. The first round of interviews was conducted approximately 2 weeks before a reduction in noise exposure (from the cessation of nighttime flights over the interview areas). The second and third rounds of interviews were conducted approximately 2 weeks and 6 weeks, respectively, after the reduction in noise exposure.

4.1.2 Examining Attitudinal Changes Following the Noise Exposure Change

Studies designed to measure the decay of the change effect also generally involve two or more sets of surveys and measurements. However, there frequently are no measurements before the change. Instead, one set of surveys or measurements occurs shortly after a change, and the second set occurs some months later. The measurements are conducted primarily to establish how much the noise exposure changes between the periods of interviews after the change; ideally the noise exposure does not change between the sets of interviews.

The Ohio Highway study is an example of such a study. Like the Los Angeles study, the Ohio Highway study involved 3 rounds of interviews: one before a change in noise exposure, and two afterwards. The first round of interviews occurred approximately 3 months before the opening of a new highway. The second round occurred 4 months after the highway opened, and the third round occurred 16 months after the highway opened. Between the second and third rounds noise exposure from the highway changed by less than 1 dB. In the first round, respondents were not asked about annoyance from highway noise. However, they were asked about annoyance due to highway noise in the second and third rounds, and much of the analysis in the study focused on the difference in noise annoyance between the second and third rounds, to test the degree to which people had adapted to the noise.

Conclusion: ***Of the 22 studies examined in this review, 13 were designed to measure the initial effect of a noise exposure change, 3 were designed to measure the decay of the change effect, and 6 were designed to measure both.***

4.2 Longitudinal and Cross-Sectional Study Designs

An important distinction between different studies is whether their designs are longitudinal, cross-sectional, or both to seek the hypothesized change effect. Each has its own advantages and disadvantages, as discussed below. Most studies reviewed here were longitudinal. That is, they involved a series of interviews and measurements at different times in the same general locale. For instance, the Heathrow study involved 2 rounds of interviews, separated by 6 years, of a sample of residents living near the airport.

By contrast, a cross-sectional study involves interviews in different locales, or of different populations (generally at about the same point in time) to seek difference effects. For instance, the Shinkansen study involved one round of interviews along each of two high speed rail lines. One line had recently opened, and the other had been in use for eight years. This study sought to quantify the abrupt change effect and its decay by comparing the results from two populations in completely separate cities.

The Atlanta study involved one set of interviews of each of two populations: people with sound insulation recently installed in their homes, and people without sound insulation. Conclusions were drawn by comparing the attitudes of the two simultaneously interviewed populations.

Many studies, such as the 10-Site, 8-Site, 14-Site, and 6-City Traffic Flow Change studies, include both longitudinal and cross-sectional elements. These studies involve longitudinal studies at a cross-section of different towns and cities.

4.2.1 Longitudinal Designs

Given that community noise studies have shown that at a particular noise exposure, community response may vary considerably between different areas (Fidell, 1991), a clear advantage of a longitudinal study is that it controls for differences in community response between different areas. Also, there may be potentially significant, area-specific variables such as the percentage of people in a community working for the airport or demographic characteristics (see Section 3 for a complete list of mediating variables) that are most easily controlled using a longitudinal design.

However, in a longitudinal study there may be variables that are confounded with the specific area or time of the study and impossible to separate from any change in response. For example, in the Roissy study, the second round of interviews was conducted in March 1975, and the third round was conducted in November 1977. Any comparison of the 1975 and 1977 data is complicated by the possibility that there could be a seasonal effect. The degree of publicity the change in noise exposure received is another variable that is difficult to control. Any publicity of the change would be confounded with the change itself. As a result of such nuisance variables and overall differences between areas, it may be difficult to generalize the results of a longitudinal study to other areas.

4.2.2 Cross-Sectional Designs

Cross-sectional studies can control for certain variables, such as season of the year, for which longitudinal studies sometimes cannot, and they are frequently more expedient. The Shinkansen high speed rail study involved interviews along the Tokaido Line, which at the time of the study had been open for eight years, and the Sanyo Line, which had been open for four months. The investigators hypothesized that the difference in sensitivity to noise between residents along the two lines (residents along the Sanyo Line were approximately 10 dB more sensitive to noise) was a result of adaptation on the part of residents along the Tokaido Line. The cross-sectional study design allowed for an expedient comparison of residents near a well-established high speed rail line with residents along a newly opened line, but the study's results are weakened by the possibility that the difference between the two groups could be a result of unknown differences between the two areas rather than adaptation to noise.

4.2.3 Combination Designs

Studies with longitudinal and cross-sectional elements can achieve the advantages of both. The traffic flow change studies conducted at multiple sites involved before/after measurements with variations in study area, time of year of the interviews and change in exposure, size of the change in exposure, and other such potentially significant factors.

Conclusion: ***Longitudinal sets of interviews, or longitudinal sets of interviews at a cross-section of areas, are a desirable element in the design of change in noise exposure studies. It is difficult to base any conclusions regarding the affect of*** *a change in noise exposure on studies with a cross-sectional design and without longitudinal sets of interviews (this includes the Atlanta, Brisbane Reduction and Shinkansen studies).*

4.3 Estimating a Baseline Dose-Response Curve

As discussed in Section 4.1, the critical issue in before/after studies is determining the magnitude of the abrupt change effect (except for the Heathrow study, in which the change was gradual). If there were no such effect then the response to a change in noise exposure may be predicted using an accurate baseline dose-response curve (one based on interviews and measurements in the absence of any change). If there is a positive abrupt change effect in response to an increase in noise exposure, then the baseline curve would under-predict the annoyance. Likewise, if there is a negative abrupt change effect in response to an increase in noise exposure, then the baseline curve would over-predict the annoyance.

To determine the existence and magnitude of the abrupt change effect, investigators essentially compare the measured change in response to the change in response predicted from a baseline dose-response curve. In studies designed to measure the decay of the change effect, the baseline curve provides an estimate of community response if the effect decays completely. In such an important comparative role, the accuracy of the baseline is of critical importance. In the literature, the baseline dose-response curve has been estimated in the following ways:

- **No Estimate of Baseline Dose-Response:** Many of the earlier (and some of the more recent) change in noise exposure studies have no estimate of the dose-response relationship in the absence of a change, generally because this was not a goal of the study, or there was not enough data to derive a curve. With no such curve, investigators may still compare the "before" and "after" community response to test whether or not there was a significant change in response. In some of these studies, such as the Heathrow and Minneapolis studies, the investigators derived dose-response curves, but did not explicitly test a baseline exposure estimate to the change in noise exposure data.

- **Estimate of the Baseline from the Schultz Curve:** After the introduction of the Schultz Curve in 1978 (Schultz, 1978), the idea of using a dose-response relationship became better-established. After 1978 most studies either included an estimate of the baseline dose-response relationship of the study area in the absence of a change, or at least they compared the results of their measurements to the Schultz Curve.

- **Estimate of the Baseline from Other Areas:** In several cross-sectional studies a baseline dose-response curve is derived from data taken at other, constant-exposure sites. Then a curve is derived from data from the area or areas where the exposure changed, and the curves are compared. Typically both the offset of the curves and the slopes are compared. This can provide a better estimate of the effect of a change than comparison with the Schultz Curve, especially if the investigator is using a response metric other than "percent highly annoyed," or has chosen sites for comparison that are very much alike except for their change in noise exposure.

- **Estimate of the Baseline from "Before" Data:** Another approach to estimating a baseline dose-response relationship is to use the data taken before the change in noise exposure. This may potentially provide the most accurate of estimate of the response expected under baseline (unchanged exposure) conditions, but requires a large amount of "before" data, along with data distributed over a wide range of noise levels.

Tables 4-1, 4-2, and 4-3 below summarize the source of the baseline dose-response estimate for each of the studies under review. The first column lists the abbreviated name of the study, the second column lists whether the study is a before/after study or an adaptation study, and the third column lists whether its design is longitudinal or cross-sectional. The next four columns provide the source (or sources) of constant noise exposure dose-response estimates.

Table 4-1. Study Designs and Baseline Exposure Estimates for Airports

Study	Designed to Measure the Change Effect or Its Decay?	Longitudinal or Cross-Sectional?	Source of Baseline Noise Exposure Dose-Response Relationship			
			None	Schultz Curve	Other Areas	"Before" Data
Heathrow	Change Effect	Longitudinal	✓			
Los Angeles	Change Effect	Longitudinal	✓			
Roissy	Both	Both			✓	
Burbank	Both	Longitudinal		✓		✓
Orange County	Change Effect	Longitudinal		✓	✓	
Oslo	Change Effect	Longitudinal				✓
Atlanta	Change Effect	Cross-Sectional			✓*	
Bodø/Værnes	Change Effect	Both			✓	

* Baseline determined from residents in untreated houses.

Table 4-2. Study Designs and Constant Exposure Estimates for Roadway Studies

Study	Designed to Measure the Change Effect or Its Decay?	Longitudinal or Cross-Sectional?	Source of Baseline Noise Exposure Dose-Response Relationship			
			None	Schultz Curve	Other Areas	"Before" Data
Huddinge	Decay of Effect	Longitudinal	✓			
Heston	Change Effect	Longitudinal	✓			
Minneapolis	Change Effect	Longitudinal	✓			
Wuppertal/Düsseldorf	Change Effect	Both				✓
10-Site Traffic Change	Both	Both			✓	
Ohio Highway	Decay of Effect	Longitudinal	✓			
6-City Traffic Change	Change Effect	Both				✓
Brisbane Reduction	Change Effect	Cross-Sectional		✓		
Brisbane Increase	Both	Longitudinal		✓		
8-Site Traffic Change	Both	Both				✓
14-Site Traffic Change	Change Effect	Both			✓	
French Barriers	Change Effect	Both	✓			

Table 4-3. Study Designs and Constant Exposure Estimates for Railway Studies

Study	Designed to Measure the Change Effect or Its Decay?	Longitudinal or Cross-Sectional?	Source of Baseline Noise Exposure Dose-Response Relationship			
			None	Schultz Curve	Other Areas	"Before" Data
Shinkansen	Both	Cross-Sectional			✓	
Zoetermeer	Decay of Effect	Longitudinal	✓			

Conclusion: ***To measure the abrupt change effect, a study must develop a robust, airport-specific baseline dose-response curve. Since prior studies strongly suggest site specificity in baseline relationships; therefore, future studies must recognize this fact in their design. Simply "using the Shultz curve" is highly unlikely to be adequate. Most of the studies in this review derive some form of baseline dose-response curve from locally-acquired data.***

4.4 Timing of Interviews Relative to Noise Exposure Changes

As discussed in Section 2.3, there are a number of dimensions to a change in noise exposure, and a number of ways in which community response may vary following a change. Depending on the design of the study, and in particular, the timing of the interviews relative to noise exposure changes, the studies in this review lead to conclusions concerning different elements of community response to a change in noise exposure. The following diagrams (Figures 4-1, 4-2, and 4-3) illustrate the timing of the interviews of most of the studies relative to the noise exposure change.

For each study shown, the noise exposure is depicted in a simplified manner on the vertical axis, and time is depicted on the horizontal axis. Note that the horizontal axes for some studies are compressed so that all of the data fits on the page. Studies without a longitudinal component have not been depicted (the Atlanta, Brisbane Reduction and Shinkansen studies), nor have studies for which the available information on the timing of the interviews is incomplete (the Wuppertal/Düsseldorf, 6-City Traffic Change, and French Barriers studies). The timing for the multi-site studies that are depicted (the 10-Site Traffic Change, 8-Site Traffic Change, and 14-Site Traffic Change studies) is somewhat approximate since the time of the exposure changes and interviews were different for each site. Additional detail about each study is presented in Appendix A.

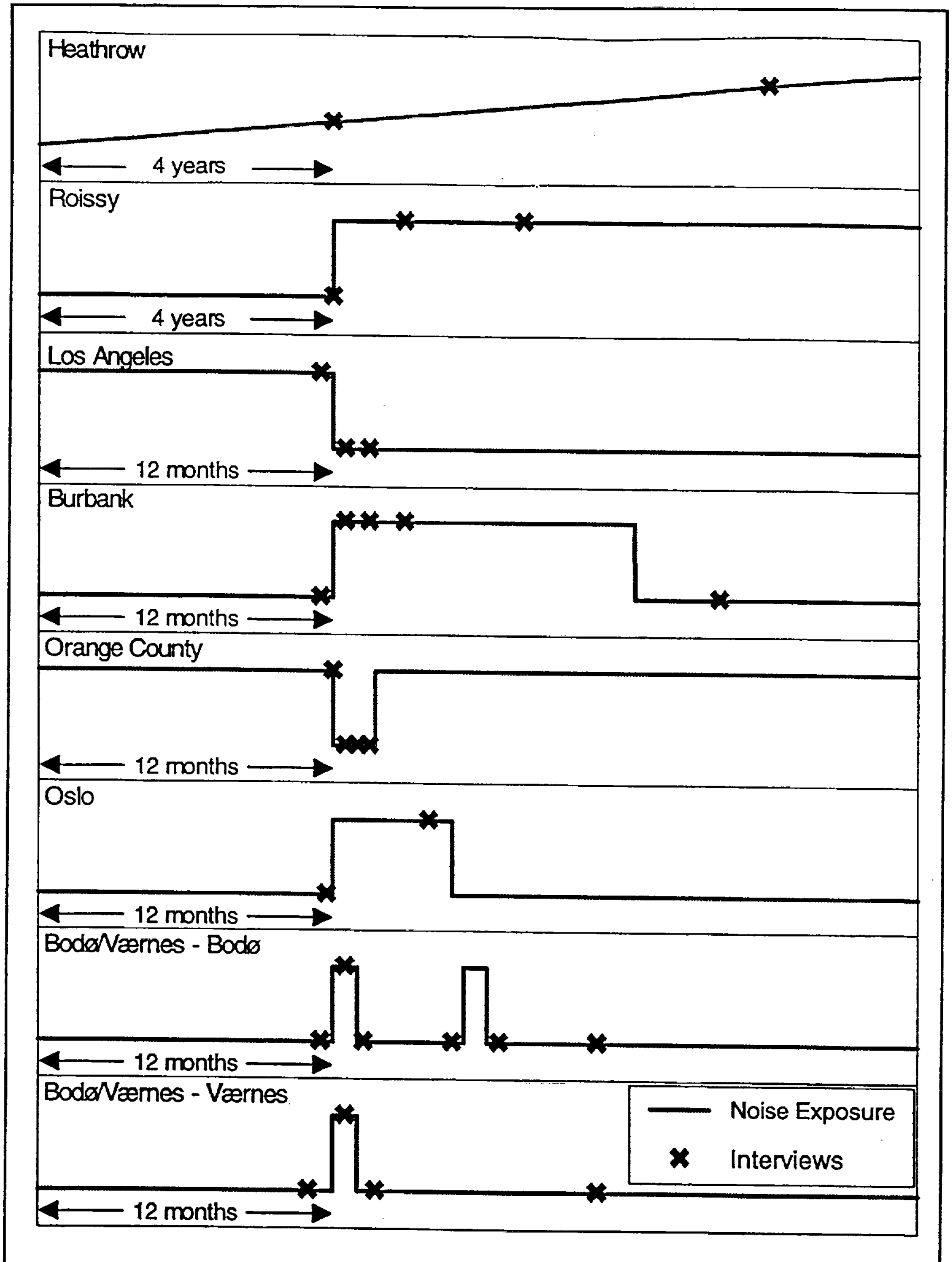

Figure 4-1. Interview Timing in Airport Studies

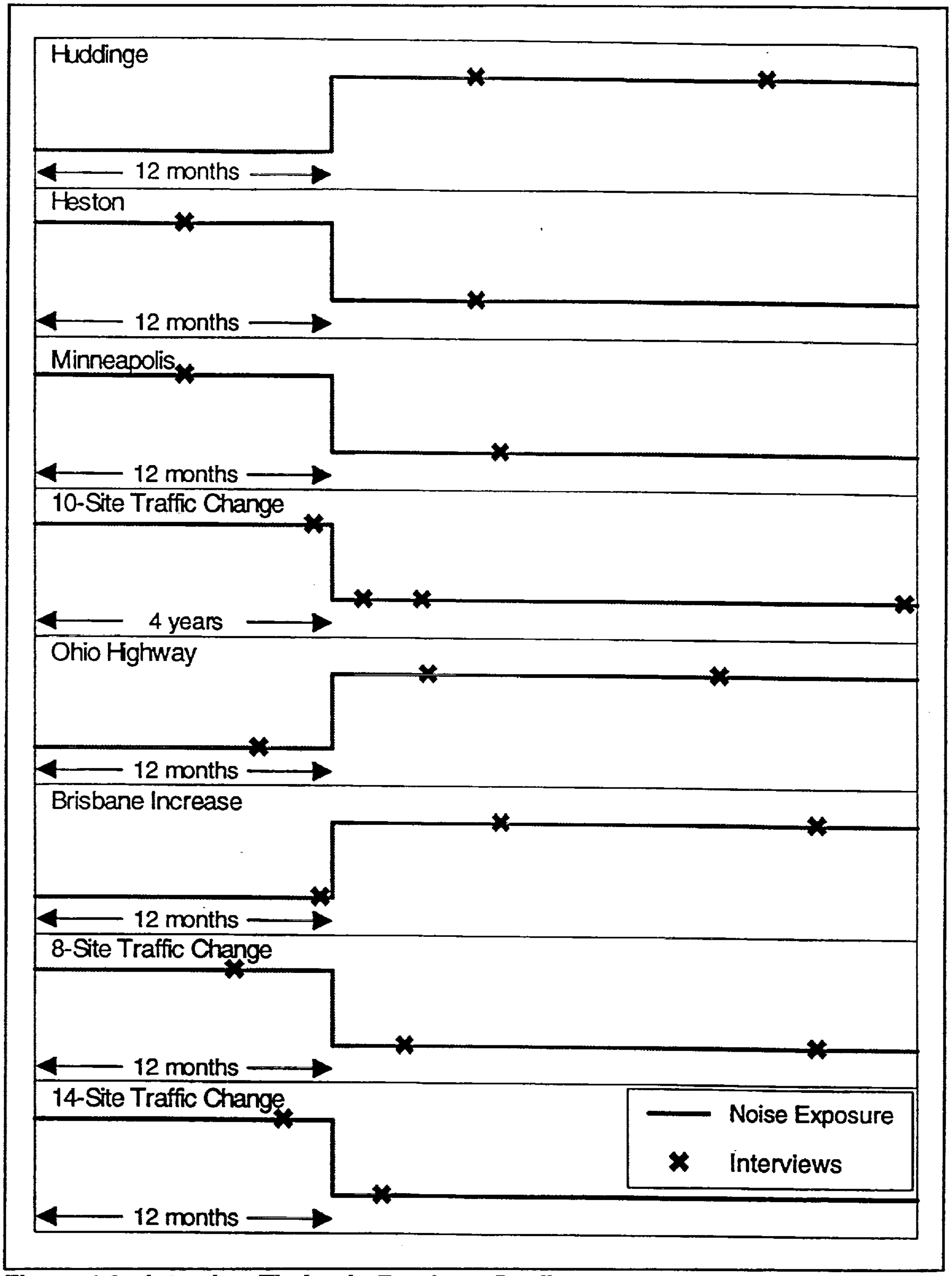

Figure 4-2. Interview Timing in Roadway Studies

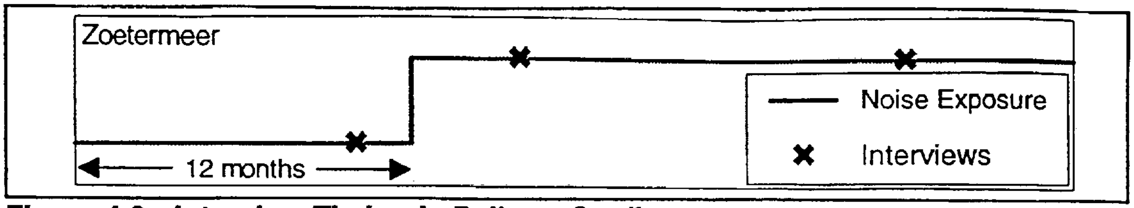

Figure 4-3. Interview Timing in Railway Studies

The diagrams in Figures 4-1, 4-2, and 4-3 lead to the following conclusions:

Conclusion: ***With the exception of the Heathrow study, the studies in this review involve noise exposure changes that occurred over a relatively short period. Typically the change occurred over a few days or weeks, compared to a gradual change over 6 years in the case of the Heathrow study.***

Conclusion: ***In the longitudinal studies, the time from the change in noise exposure to the first "after" interview varies from approximately 2 weeks (Burbank, Orange County, Bodø/Værnes) to 12 months (Roissy) after the initial change in noise exposure. Thus, these studies could not measure the abrupt change effect in the event that it occurs and then decays within a few days after a change in noise exposure.***

Conclusion: ***The studies that measured the decay of the change effect typically compared responses measured at least 2 months after a change to responses measured a least 15 months after a change.***

4.5 Study Population Selection

There are large variations in the selection and size of study populations in the change in noise exposure studies in this review. While the Brisbane Increase study involved interviews with a small group of 22 respondents who lived near a particular road, the 6-City Traffic Reduction study involved interviews with over 3,400 respondents in 50 clusters scattered between 6 cities.

Tables 4-4, 4-5, and 4-6 summarize the study populations for the airport, roadway and railway studies, respectively. The first column of each table lists the abbreviated study name. The second column lists how interview areas were selected, either as clusters of residences (generally with near-equal noise exposure), or using noise level contours, or by selecting all of the residences within a certain proximity of the noise source. The third column in the table lists the number of rounds of interviews. The fourth column lists the number of response units (persons, residences, depending on how study tabulated interviews) who participated in the study, and the last column lists the number of interviews conducted. The numbers of interviews and respondents for each study are summarized graphically in Figures 4-4, 4-5, and 4-6.

The method of selection of interview areas, whether by clusters, noise level contours, or proximity to the noise source, is a critical issue in the data analysis. As discussed in Appendix B of the Oslo report, simple random sampling assumptions are not appropriate in studies based on clustered samples. Also, simple random sampling assumptions cannot be made when an *entire* population has been sampled (such as all of the residents living along a road).

4.5.1 Clustered Samples

Half of the studies in this review used clustered samples. Of the entire population exposed to a particular noise source, clusters with near-equal noise exposure were selected. The clusters could have been chosen based on their proximity to a flight path, because they represented the heaviest concentration of residences in the vicinity of a source, or for other reasons. Within the clusters, sampling was generally either random (a certain number or proportion of households were selected randomly with replacement), or exhaustive (every household was selected).

4.5.2 Noise Level Contours

The Atlanta, Burbank, Roissy and Ohio Highway studies involved selection of interview areas based on noise level contours. First the contours were drawn to characterize the noise source. Then they were super-imposed upon a map, and the area between particular noise contours was sampled. In the Atlanta, Roissy and Ohio Highway studies the contours also served to quantify respondent doses. At Burbank, the contours were used only to establish small neighborhoods with a limited exposure range. Doses were determined empirically by continuous, week-long measurements at the centroid of each neighborhood.

4.5.3 Proximity to Source

Studies in which the interview areas were selected based on proximity to the noise source (with the exception of the Heathrow study) were concentrated on small populations near a particular section of a road or near a noise barrier.

4.6 Repeat versus Non-Repeat Interviewing

An important element of the study design is the decision of whether to purposefully sample the same respondents each interview round (a panel sample), or to avoid doing so. Sampling the same respondents over again may help to control for person-to-person differences, but there is a possibility that the survey responses are biased by repeated interviews. If repeat interviews are used, a group of people interviewed only once can provide an estimate of the potential that the repeat interview group was biased. Using repeat interviews researchers reported that the group of respondents tends to shrink over time.

For instance, in the Ohio Highway study, a group of respondents was interviewed three times (once before, twice after the change). During the second and third rounds of interviews separate groups were interviewed that were composed of residents who had not been interviewed in previous rounds. The second round annoyance for the repeat interview group was significantly lower than (1) the annoyance for the non-repeat group and (2) the annoyance for the repeat interview group in the third round (noise exposure did not change significantly between the second and third rounds of interviews). The investigators hypothesized that in the second round of interviews the repeat interview group had been biased by the first round surveys, which had taken place seven months before. Other studies had a similar combination of repeat and non-repeat interview groups, although there frequently was no significant difference between the two groups.

A comparison between the number of respondents and the number of interviews in a study provides a straightforward measure of the extent to which the same respondents were re-interviewed. Most of the studies involved some form of repeat interviews. However, in some studies with "partial panels" (Burbank and Orange County), the investigators did not record exactly which people were interviewed how frequently. In other studies (Oslo, 6-City Traffic Change) the investigators purposefully avoided re-interviewing the same respondents. The study descriptions in the appendices detail the design of each study.

Conclusion: ***If a change in noise exposure study involves re-interviewing the same respondents, there exists the possibility that the first interview will create a bias in the respondent's subsequent interviews. Separate groups of respondents interviewed only once can be used to test for such bias.***

Conclusion: ***The studies in this review typically involved 2 to 3 rounds of interviews with 400 to 5,700 total interviews. Most of the studies in this review involved some form of repeat interviewing. In some studies the investigators purposefully avoided re-interviewing the same individuals. Future studies should use some combination of repeat and non-repeat interviewing.***

Table 4-4. Study Populations of Airport Studies

Study	Selection of Interview Areas[1]	Rounds of Interviews	Total No. of Response Units	Total No. of Interviews
Heathrow	proximity	2	4,849[2]	4,849
Los Angeles	3 clusters	3	940	1,417
Roissy	contours	3 (Roissy) 1 (Orly)	2,412	3,114
Burbank	4 clusters	5	>1,000	>5,000
Orange County	3 clusters	4	>890	3,103
Oslo	15 clusters	2	3,354	3,354
Atlanta	contours	1	941	941
Bodø/Værnes	clusters	6 (Bodø) 4 (Værnes)	4,080	5,727

Notes:

1. Method of selection of interview areas: generally areas where chosen using criteria based on **proximity** to the noise source, noise level **contours**, or as **clusters** with near equal noise exposure.
2. This number is likely slightly high because a small number of people could have been re-interviewed between rounds.

Table 4-5. Study Populations of Roadway Studies

Study	Selection of Interview Areas[1]	Rounds of Interviews	Total No. of Response Units	Total No. of Interviews
Huddinge	proximity	2	84	144
Heston	proximity	2	316	458
Minneapolis	proximity	2	151	272
Wuppertal/Düsseldorf	proximity	2	174	312
10-Site Traffic Change[2]	clusters	4	>500	>1,400
Ohio Highway	contours	3	260	504
6-City Traffic Change	50 clusters	2	3,405	3,405
Brisbane Reduction	proximity	1	101	101
Brisbane Increase	proximity	3	22	62
8-Site Traffic Change	clusters	3	469	950
14-Site Traffic Change[2]	clusters	2	>700	>1,400
French Barriers	2 clusters	2	75	150

Notes:

1 Method of selection of interview areas: generally areas where chosen using criteria based on **proximity** to the noise source, noise level **contours**, or as **clusters** with near equal noise exposure.

2 Numbers do not include interviews conducted from other studies which were used to derive baseline dose-response curves.

Table 4-6. Study Populations of Railway Studies

Study	Selection of Interview Areas[1]	Rounds of Interviews	Total No. of Response Units	Total No. of Interviews
Shinkansen	clusters	1	424	424
Zoetermeer	clusters	3	454[2]	945

Notes:

1 Method of selection of interview areas: generally areas where chosen using criteria based on **proximity** to the noise source, noise level **contours**, or as **clusters** with near equal noise exposure.

2 The analysis was based on the data from 133 respondents interviewed in each round.

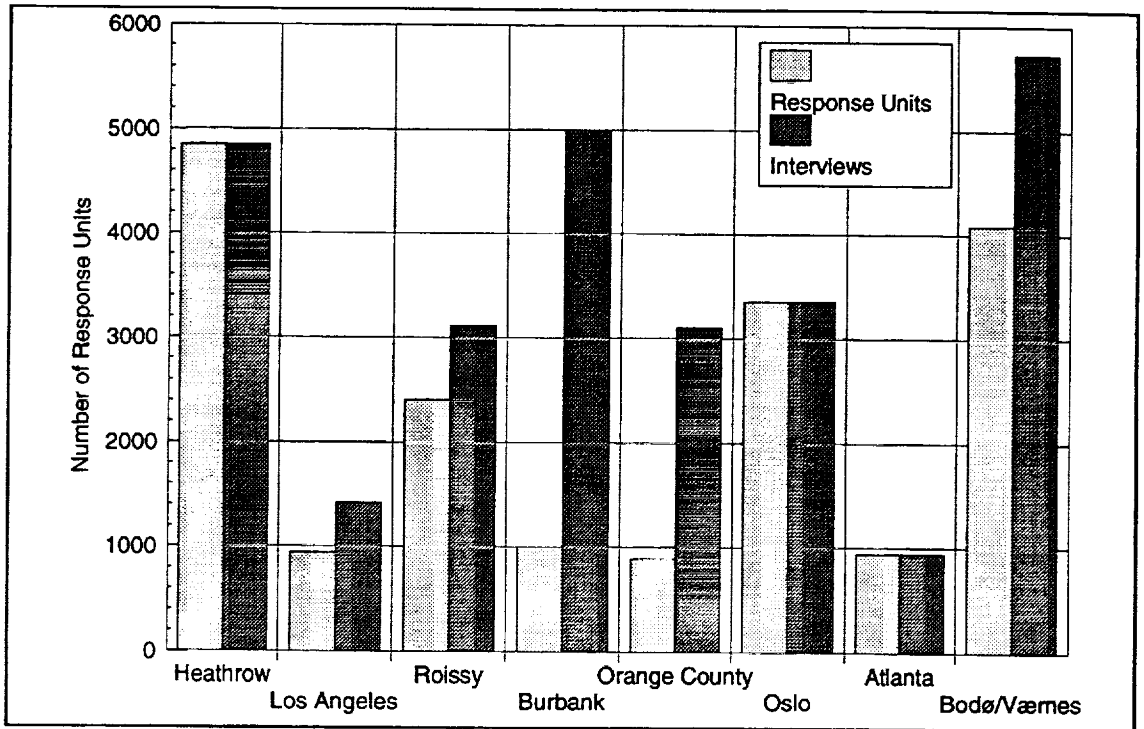

Figure 4-4. Study Samples of Airport Studies

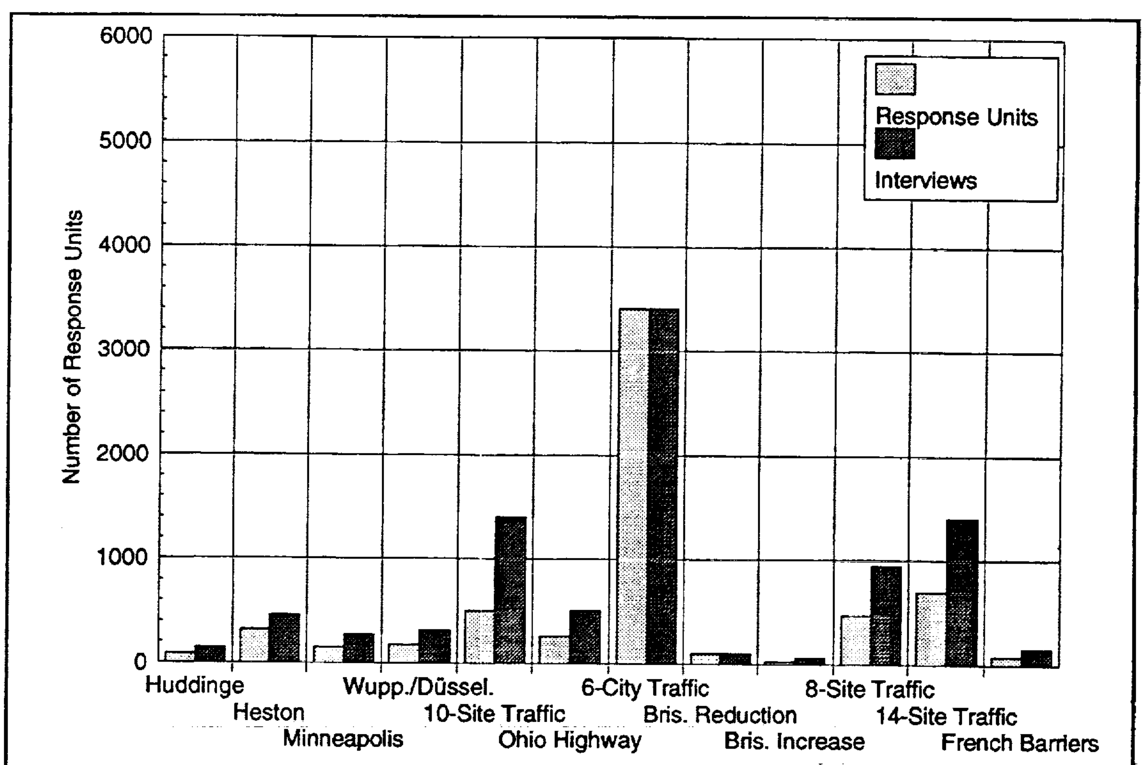

Figure 4-5. Study Samples of Roadway Studies

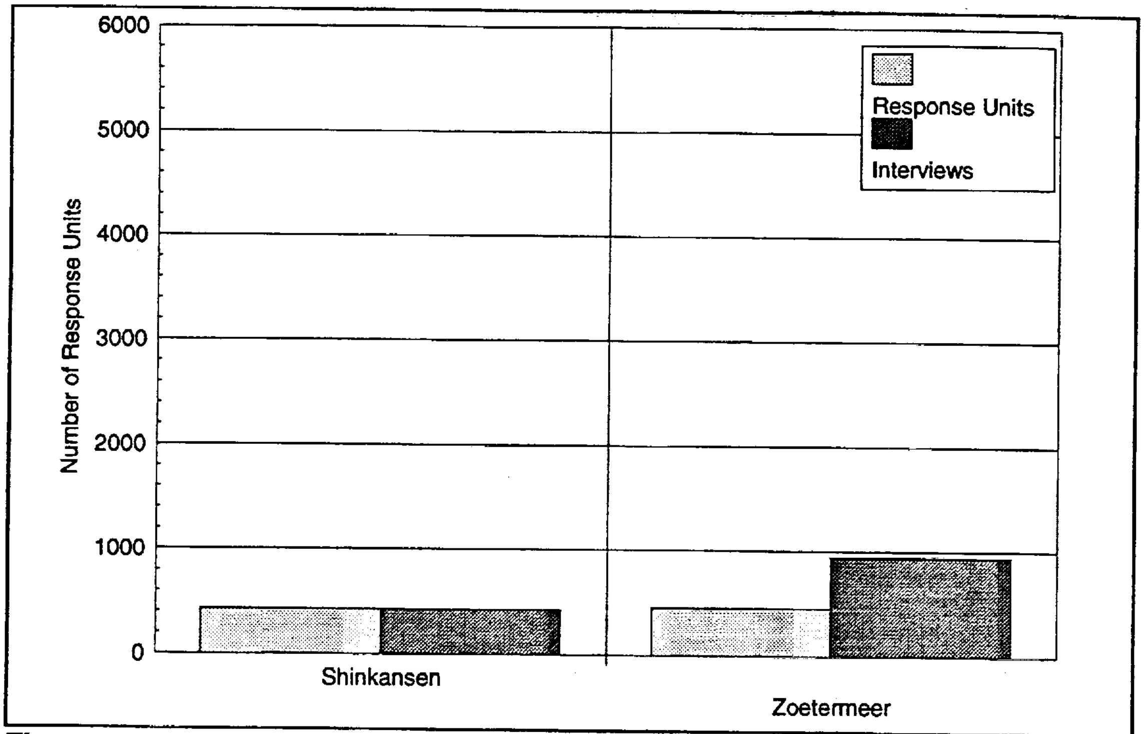

Figure 4-6. Study Samples of Railway Studies

5. ACOUSTIC DOSE DETERMINATIONS

All 22 studies examined in this review, with the exception of the Huddinge study, employed one or more indices of daily (or near 24-hour), outdoor noise exposure (DNL, L10, etc.) to quantify the acoustic dose of each attitudinal survey respondent. Three of the indices (the British Noise and Number Index, NNI, the Weighted Equivalent Continuous Perceived Noise Level, WECPNL, and the French Isopsophic Index, *N*) use the Perceived Noise Level (PNL) as the underlying measure of time-varying noise. The rest of the indices (DNL, EFN, equivalent levels, and centile levels) use the A-weighted sound level as the underlying measure.

The studies either *predicted* the noise exposure using an appropriate noise prediction model, measured the daily exposure at or near the respondents' residences, or used a combination of both techniques. This section discusses various aspects of dose determination, including the metrics used, the mechanics of the measurement and estimation process, the consistency of approach across rounds of interviewing, and probable errors of estimate in the dose estimates.

Tables 5-1, 5-2 and 5-3 provide a summary of acoustic dose information for the airport, roadway and railway studies, respectively. The first and second columns of the tables identify the study and the date it was undertaken. The third column shows the dose metrics investigated by each study. The fourth column summarizes the manner in which the dose(s) were estimated. The fifth column indicates whether the noise exposure change was due to the introduction of a new target noise source, or whether it resulted from a change in a pre-existing source. The last column shows whether or not error bounds on the dose variable were discussed.

5.1 Dose Metrics Used

Table 5-4 summarizes the 15 different acoustic dose metrics upon which dose-response relationships were established. Many studies correlated attitudinal responses with more than one dose metric; hence, there is a greater aggregate frequency of mention in the table than there are numbers of studies reviewed. The left hand column of the table subdivides the metrics into two groups: energy (or energy-like) metrics, and centile metrics. In general, the aircraft studies favored the energy metrics (which account for sound level, number of noise events, and time of day. These include DNL, EFN, *N* and NNI. The finding is not surprising in light of the fact that these metrics were developed specifically to treat aircraft noise environments. With DNL and EFN very closely related A-level based metrics, the basic DNL concept was used in 3/4 of the airport surveys.

Roadway studies favored energy average A-weighted sound levels (with a range of integration periods from 8 to 24 hours), and centile levels (also with a range of integration periods). The predominant roadway metrics were the 24-hour Leq and the 18-hr L10. Together they account for just under 60 percent of the roadway studies reviewed. Centile levels have a long history as roadway noise indices, so this finding is not surprising either. One railway study used 24-hour Leq, and the other used both PNL and WECPNL.

Conclusion: ***The predominant acoustic dose in the airport studies is DNL. In the roadway and railway studies 24-hour Leq and 18-hour L10 are the predominant acoustic doses.***

Table 5-1. Dose Attributes of Airport Studies

Study Name	Year	Dose Metric(s)	Mechanics of Estimation	New Source ?	Error Bounds Cited
Heathrow	1967	NNI	Contours & Measurement	No	No
Los Angeles	1973	DNL	Contours & Measurement	No	No
Roissy	1977	***N***	Contours	Yes	No
Burbank	1980	DNL	Contours & Measurement	No	+-2 dB
Orange County	1981	DNL	Contours & Measurement	No	No
Oslo	1989	EFN	Contours & Measurement	No	No
Atlanta	1990	DNL	Contours	No	No
Bodø/Væmes	1992	EFN	Contours & Measurement	No	No

Table 5-2. Dose Attributes of Roadway Studies

Study Name	Year	Dose Metric(s) Measured	Mechanics of Estimation	New Source ?	Error Bounds Cited
Huddinge	1967	DK	Measurements	Yes	No
Heston	1970	L10(18-hr)*, L10(24-hr)	Measurements	No	No
Minneapolis	1972	L10, L50, L90, Leq* (all 14-hr)	Measurements	No	No
Wuppertal/ Düsseldorf	1982	Leq (24-hr)	Measurements	No	No
10-Site Traffic Change	1981	L10 (18-hr)*, Leq	Traffic Counts & Measurements	No	No
Ohio Highway	1978	Leq (24-hr)	Measurements	Yes	No
6-City Traffic Change	1980	Leq (24-hr)	? ?	No	No
Brisbane Reduction	1980	DNL*, L10(18-hr)	Spot Measurements	No	No
Brisbane Increase	1980	DNL*, Leq(24-hr), L10(18-hr)	Spot Measurements	No	No
8-Site Traffic Change	1986	L10(18-hr)	Traffic Counts & Measurements	No	No
14-Site Traffic Change	1991	L10(18-hr)	Traffic Counts & Measurements	No	No
French Barriers	1991	Leq(8-hr), Leq(20-hr)*	Don't Know	No	No

* Primary measure used in analyses

Table 5-3. Dose Attributes of Railway Studies

Study Name	Year	Dose Metric(s)	Mechanics of Estimation	New Source ?	Error Bounds Cited
Shinkansen	1972	PNL, WECPNL	Contours & Measurements	Yes	No
Zoetermeer	1977	Leq(24-hr)	Train Schedules & Measurements	Yes	No

Table 5-4. Summary of Dose Metrics

Category	Metric	Number of Studies Using Metric		
		Air	Roadway	Rail
Energy or Pseudo-Energy Metrics	DNL	4	2	
	EFN[1]	2		
	N[2]	1		
	NNI[3]	1		
	PNL[4]			1
	WECPNL[5]			1
	Leq (8-hr)		1	
	Leq (14-hr)		1	
	Leq (20-hr)		1	
	Leq (24-hr)		5	1
Centile Metrics	L10 (24-hr)		1	
	L10 (18-hr)		6	
	L10 (14-hr)		1	
	L50 (14-hr)		1	
	L90 (14-hr)		1	

Notes:
[1] Equivalent Aircraft Noise Level, EFN ≈ DNL + 1 dB
[2] Isopsophic Index
[3] Noise and Number Index
[4] Perceived Noise Level
[5] Weighted Equivalent Continuous Perceived Noise Level

5.2 Methods for Determining Respondent Doses

The noise dose is clearly *the* major independent variable in dose-response studies. There are basically two issues involved in determining each respondent's dose:

- Ensuring that the dose is calculated for the same period of time that the respondents were asked to consider in providing answers to the questionnaire, and

- The mechanics by which the dose is determined for each respondent.

5.2.1 Temporal Issues

In approximately one-third of the studies, a specific time period was incorporated in the survey question on annoyance. In these cases, respondents were asked to consider a very specific time period (past week, past month, past year, etc.) when forming their response about the noise source. Hence, the dose estimate had to attempt to match that period as closely as possible. Fidell, et al (1981) demonstrated the importance of specifying a time period by showing that respondents do, in fact, focus on a specified period of time when asked (eg. past week, past month, past year), and provide responses consistent with average noise exposure during those periods.

A legitimate question is whether the respondent can focus in on the precise time frame specified by the questionnaire. The most critical period for time alignment is "past week," since the specified time frame (and the response) in this case is highly dependent upon when the interview took place. In the case of the Burbank study, where a "past week" response was requested, the method used to ensure time alignment was to limit the length of the interviewing period. This was accomplished by conducting all face-to-face interviews in one day (a Saturday). All follow-up telephone interviews began later that Saturday afternoon and were completed by the end of the next day (Sunday).

It is not established what period should be considered when attempting to integrate past studies in which a time period has not been specified in the survey. This leads to uncertainty in the acoustic dose measurements. It may also lead to additional variance in observed annoyance as different people consider different time frames for their response.

5.2.2 Mechanical Issues

The second issue has to do with the mechanics of determining the dose. Throughout all of the studies, three basic strategies were used to estimate a respondent's dose: (1) field measurements, (2) noise contours using an appropriate noise prediction model, and (3) a combination of both measurements and contours, using the measurements to "calibrate" the contours. Although few studies discussed the issue of dose measurement uncertainty, it is clear by the descriptions provided in the literature that some methods were inherently more accurate than others. For example, in the Roissy airport noise survey, the dose was determined entirely by government-supplied noise contours, presumably generated by a then state-of-the-art computer simulation model. Considering the time frame (early to mid 1970's), airport noise prediction models were in their infancy, as were modelling techniques, ability to validate aircraft noise and performance databases, and acquiring airport, runway, and flight corridor use statistics. All told, a conservative estimate of the dose uncertainty under such conditions would be ±5 decibels, perhaps more. Furthermore, for the second round of interviews after the exposure change, the contours for the entire airport were increased by a constant, 1 decibel. This constant was determined from general air traffic increase statistics and apparently did not reflect an assessment of whether general operating procedures affecting runway use and the like had occurred.

In contrast, the Burbank study incorporated both contours and measurements. The contours were used to select neighborhoods with no more than a 5 decibel range in dose. For one week prior to each round of interviews, continuous noise monitoring took place at one or more locations in the interview neighborhoods. These measurements were used to adjust the level of the noise contours up or down depending on the outcome. The survey respondents were asked to consider only the past week in determining their level of annoyance, the exact time from of the monitoring. Using this technique, the dose uncertainty was reported as ±2 decibels.

Between these extremes a full range of techniques were found. For highway noise studies measurements were often conducted for very limited periods of time (less than one day) and in limited locations (near the first row of houses paralleling the roadway) and estimates made regarding the sound level drop-off rate with increasing distance (rows of houses) from the roadway.

Microphone height and placement, and the ability of the noise level measurement process to discriminate between the target source and other community sources was rarely discussed in the literature. These unquantified variables were not necessarily constants equally affecting all measurement locations for a single study. Variations across measurement sites (affecting the establishment of both a baseline dose-response relationship as well as the magnitude of exposure change for affected neighborhoods) of only 0 to 3 decibels would not be surprising

In summary, dose uncertainty has been a critical issue in past studies. While it is apparent that researchers did the best they could insofar as dose estimation was concerned, the magnitude of exposure change effects being sought were apparently of about the same magnitude (or even smaller) than the uncertainty in dosage within any of the respondent pools. This critical issue must be addressed in any future studies and their design..

6. POTENTIAL MEDIATING AND CONFOUNDING VARIABLES

Mediating variables, such as the demographics of the study area or residents' attitudes and expectations concerning a noise source, are important. They may have a large influence on the results of a change in noise exposure study. On the one hand, determining the influence of potential mediating variables adds confidence to interpretation of the study results. On the other hand, omitting an analysis of mitigating variables may make it virtually impossible to draw conclusions about the major study variables.

This section discusses mediating variables applicable to change in noise exposure studies. Section 6.1 describes the types of mediating variables examined or of interest in change in noise exposure studies. Section 6.2 focuses on mediating variables that are highly correlated (confounded) with the change in noise exposure or other mediating variables, and can greatly complicate the interpretation of a study's findings.

6.1 Types of Mediating Variables in Change in Noise Exposure Studies

Mediating variables, in this case the variables besides the acoustic dose that may influence a dose-response relationship, are a factor in nearly every community noise study. Section 3 lists mediating factors that might be included in a model relating noise exposure and noise exposure changes to annoyance. For the purpose of this review, mediating variables may be grouped in the following categories:

Interview Area: As discussed in Section 4 there are often large site-to-site differences in noise sensitivity. For this reason, the results of a study that apply to one particular area, such as the baseline dose-response curve derived for Burbank Airport, or the finding that residents near Bodø Airport did not become more annoyed by a temporary, 6 dB increase in noise exposure, do not necessarily apply to other locations. Given the complexity of accounting for differences in sensitivity between different areas, few studies have tried to account for this factor. Most studies have been conducted in one particular area (near one road or in an area near an airport), and the studies that involve multiple sites tend to avoid accounting for the overall differences between sites.

Demographics: These variables, which include respondent age, gender, socio-economic status, income, education, dwelling type and ownership, employment, and other factors, have been examined in a number of studies. Of these, length of residence is often of particular concern in change in noise exposure studies, since new residents may not have experienced the recent change in noise exposure.

Another critical point about length of residence is that it could well be correlated with the time elapsed since the noise exposure change. If recent residents' opinions change in the first few months then even if they had been present for the entire period there would be a confounding of effects. Even if the other demographic variables were important, the demographic variables seem to be more likely to increase the variance than create a bias in the estimates.

Previously, Fields (1992) performed a meta-analysis examining the effects of a number of personal and situational variables. The meta-analysis incorporated the results of a large number of noise studies, including most of the studies examined in the current review. Based on this meta-analysis, the balance of the evidence indicates that demographic variables have no more than a small effect on annoyance (Fields, 1992, p. 30).

Attitudes and Expectations: This category covers a large number of difficult-to-quantify variables, such as residents' general opinion of the noise source, their opinions of the neighborhood, attitudes about potential sources of annoyance related to the noise source (such as air pollution, dust, and glare), attitudes about the activities that led to the change in noise exposure (efforts to reduce traffic, construct a noise barrier, or open an airport), and numerous other factors.

From Fields' meta-analysis it is clear that attitudes and expectations influence noise annoyance (Fields, 1992, p. 30). A number of studies in the current review (such as the Heathrow study, Ohio Highway study, and 6-City Traffic Change study) have reached this conclusion, also. One thorny issue is the causality between attitudes and expectations versus noise annoyance. That is, do people who are annoyed by noise develop negative attitudes due to their annoyance, or do a person's attitudes and expectations influence their annoyance rating?

Of the studies in the current review, the Ohio Highway study presents a particularly interesting treatment of attitudinal variables. In this study, respondents answered a number of questions concerning their attitudes and expectations before the change in noise exposure caused by the opening of a new highway. For these responses, Weinstein estimated respondents' "critical tendencies," a parameter reflecting their predisposition towards expressing perceived annoyance. The critical tendencies were then used to reduce the scatter in the relationship between noise and annoyance experienced after the change .

Temporal Variables: These are variables that may influence response to a change in noise exposure and have a strong time-varying component. For this reason, they frequently correlate well with a change in noise exposure. For instance, the weather (measured in terms of average temperature or some other metric) may be an important variable in a change in noise exposure study. If residents are less annoyed during cold weather when windows are more frequently closed, then a study that involves measurements in two different seasons before and after a noise exposure change may be compromised unless it can account for the influence of this variable. Another potentially significant, temporal variable is changes in traffic that may occur in certain areas as a function of the time of year, such as near vacation areas.

Tables 6-1, 6-2, and 6-3 summarize the treatment of mediating variables in the airport, roadway, and railway studies, respectively. The first column of each table lists the abbreviated study name. The next four columns detail which types of mediating variables are examined in each study. The last column of the table gives a one-line summary of the level of analysis. If mediating variables were examined as part of the analysis, then the column shows one of the following:

Description: The potential significance of mediating variables was discussed.

Tabulation: Mediating variables were tabulated and reported, generally by interview area. There is little or no analysis of the relationship between mediating variables and annoyance.

Comparison: In addition to tabulation of the mediating variables, some sort of comparison is made of the differences in the value of mediating variables between study areas, or of the relationship between the mediating variables. For instance, in the Shinkansen study the investigators report that they tested and found no correlation between annoyance and the demographic variables age and length of residence.

Estimate of Effects: In two studies, the Oslo Airport and Ohio Highway studies, the investigators included mediating variables in their regression, thus estimating the decibel-equivalent effect of different variables. It is possible that other investigators also performed such regressions for their studies, but such results are not presented in the available literature.

Table 6-1. Treatment of Mediating Variables in Airport Studies

Study	Interview Area	Demo-graphics	Attitudes/ Expecta-tions	Temporal Variables	Level of Analysis
Heathrow		✓	✓		comparison
Los Angeles		✓			tabulation
Roissy		✓	✓		comparison
Burbank		✓			tabulation
Orange County		✓			comparison
Oslo	✓	✓	✓	✓	est. of effects
Atlanta		✓	✓		comparison
Bodø/Værnes				✓	tabulation

Table 6-2. Treatment of Mediating Variables in Roadway Studies

Study	Interview Area	Demo-graphics	Attitudes/ Expecta-tions	Season	Level of Analysis
Huddinge					none
Heston			✓		tabulation
Minneapolis		✓	✓		tabulation
Wuppertal/Düsseldorf			✓		tabulation
10-Site Traffic Change			✓		tabulation
Ohio Highway		✓	✓		est. of effects
6-City Traffic Change			✓		discussion
Brisbane Reduction		✓			tabulation
Brisbane Increase		✓			tabulation
8-Site Traffic Change			✓		discussion
14-Site Traffic Change			✓		discussion
French Barriers			✓		tabulation

Table 6-3. Treatment of Mediating Variables in Railway Studies

Study	Interview Area	Demo-graphics	Attitudes/ Expecta-tions	Season	Level of Analysis
Shinkansen		✓			comparison
Zoetermeer		✓	✓		comparison

6.2 Potentially Confounding Variables

In every study there is some degree of confounding between mediating variables and noise exposure, or between mediating variables and other mediating variables. For instance, in most of the studies in this review, the change in noise exposure is confounded with a particular time and a specific area or a small number of neighborhoods near a particular noise source. Strictly speaking, it is not possible on statistical grounds to generalize the results of such studies to other exposure-change situations. Given that some level of confounding is unavoidable, an important consideration is how to best avoid a situation when it is impossible to separate the effect of a change in exposure from some other confounding effect. Frequently the best way to avoid problematic confounding is through a careful study design.

Potential confounding variables found in the studies in this review are discussed below:

Interview Area: As discussed in Section 6.1, there frequently are differences in sensitivity between different interview areas. Most of the studies in this review are concentrated in one area or a small group of areas. Confounding can be minimized by finding different noise exposures and different noise exposure changes within each area, or by measuring at a number of areas or sites. If multiple sites are measured, or a clustered sample is used, then the error analysis should reflect the uncertainty introduced by such a sample. A number of studies have looked a changes at multiple sites, but these multi-site studies (such as the 10-Site, 6-City, 8-Site, and 14-Site Traffic Change, and Wuppertal/Düsseldorf studies) generally provide little or no analysis of site-to-site variation. The Oslo study provides the most complete treatment of calculation of the uncertainty from a clustered sample. In this study, measurements were conducted in 15 clusters of residences near Oslo Airport Fornebu.

Length of Residence: As discussed in the previous section, demographic variables are generally not expected to have a significant effect on annoyance. Fields (1992) examined the possible effect of moving and determined that conclusions about this issue were not definitive based on prior investigations. However, the length of residence may be of concern in *change* in noise exposure studies, particularly in studies of the decay of the change effect in the time following a change in noise exposure. Studies that use repeat interviews following a change must account for respondents who move away following a change in noise exposure. The question is: "Was the noise exposure a factor in their moving?" Also, a change in noise exposure study may be particularly concerned with the issue of whether or not long-time residents are more or less sensitive to a change. In studies involving surveys long after a change (6 years or more), such as the Shinkansen and 10-Site Traffic Change studies, there may be a self-selecting population of people who have remained in a neighborhood since the change. Many of the noise-sensitive population may have left, leaving a relatively insensitive group (compared with the population at large) available for interviews.

Attitudes and Expectations: Respondents' attitudes and expectations are frequently confounding variables in change in noise exposure studies. For instance, in the Heathrow study, the gradual increase in noise exposure between 1961 and 1967 was confounded with a reduction in the fear of air crashes. That is, in 1967 respondents were less afraid of crashes. Also, by 1967 a greater percentage of residents had actually travelled by air. This change in attitudes may very well have had an effect on annoyance. Another issue is that residents living directly beneath a flight corridor may react differently from similarly noise-exposed people due to fear of an incident. The Oslo study addresses this issue, and concludes that there is a possible effect.

In the roadway studies that involve noise reductions through barriers (the Heston, Minneapolis, Wuppertal/Düsseldorf, and French Barriers studies) the noise exposure change is necessarily confounded with residents' attitudes about the barrier. Do residents approve of the barrier? Is it too high or too low? Do they think the government spent too much money, or are they happy someone is addressing their noise problem? Most of the barrier studies examine respondents' attitudes, but it is difficult to establish what causes the change in annoyance in these studies, is it preconceived expectations, the noise change itself, or a combination of the two? Other studies may have similar complications, such as a negative reaction to pre-change publicity, or even reacting positively because the change was much less than expected from negative pre-change expectations.

Season: The season in which noise measurements and interviews are conducted may or may not be a significant factor, and is frequently confounded with the change in noise exposure. In some cases, such as near vacation areas, traffic (and, thus, noise exposure) may vary as a function of season. Also, in colder months residents are known to keep their windows closed more consistently than in warmer months, which affects indoor noise levels. Season also affects the amount of time and the types of activities performed out-of-doors.

Many of the studies in this review attempt to control for seasonal differences, either by conducting all of the interviews within a short period (such as the Shinkansen and Atlanta studies) measuring at one-year intervals (such as the Ohio Highway, and Huddinge studies), or by measuring at times with similar weather (such as the Los Angeles, Orange County, and Oslo studies). The Bodø/Værnes study involves numerous interviews at different times of the year, but does not explicitly test for a seasonal effect.

One of the studies in this review, the 10-Site Traffic study, tests for seasonal changes in its baseline curve by measuring at the same sites (with relatively constant noise exposure) in different seasons. The results of this study (Griffiths, et al, 1980) show no seasonal effect. Although the temperature range was only 17 Fahrenheit degrees (his study extended from December 1977 to April 1978, and may have missed the hottest months of the year), it did establish correlation between temperature and reported number of windows open ($r = 0.91$). Griffiths explains the lack of a temperature effect by the theory of perceptual constancy. The theory holds that one's perception of a phenomenon (like roadway or aircraft noise level) is more governed by its source characteristics than by any modified characteristics resulting from filtering (such as by house insulation or barrier attenuation), if the individual is aware of the intervening filter.

Intervening Factors: In longitudinal studies the passage of time is a key independent variable. Sometimes, however, the passage of time works against the goals of the study. As the passage of time by itself is hypothesized to modify the intensity of response to noise exposure, other factors beyond the control of the researcher may change over time as well, and confound with the elapsed time variable. Examples include a change in community/airport relations, a nearby aircraft incident, and a change in the general political climate, to name a few. Some method to account for this potential bias is desirable, but just detecting its presence would be valuable. Closing the loop with a direct, validation question such as "Do you feel the same now as you did just after the change occurred?" and Why?" could prove immensely valuable.

Conclusion: ***Most of the studies in this review at least tabulate values for certain mediating variables involving demographics and residents' attitudes and expectations. Only the Oslo and Ohio Highway study attempted a complete analysis of mediating variables, including calculating the uncertainty introduced by a clustered sample (Oslo study) or estimating the dB-equivalent effects of mediating variables. Given the very likely importance of mediating variables in a change-in-exposure study, follow-on work should carefully examine this entire issue, and methods should be devised to quantify mediating variables. For example, media coverage could be quantified by column-inches of news articles, types of television coverage (general news, news magazines, etc.) and the frequency of occurrence.***

Conclusion: ***Specific study areas/sites, residents' length of residence, attitudes and expectations, and seasonal variations are frequently confounded with changes in noise exposure. The problems introduced by these potentially confounding variables are not intractable, but should be carefully considered in the study designs of any future research.***

Conclusion: *Attitudes and expectations, in particular, should be carefully considered in future research. If possible, the concept of "critical tendencies," as discussed in the Ohio Highway study, should be used to explore differences between study areas and to reduce the scatter in dose-response relationships. The causality of annoyance due to noise and attitudes towards the source are two quite different variables. Future studies should carefully consider these two variables and the study design should explicitly tease them apart..*

7. RESPONSE MEASURES

This section summarizes the response measures in the 22 studies in this review. Section 7.1 provides an overview of the survey instruments. Section 7.2 discusses the lengths of interviews in the studies, and Section 7.3 discusses different scales used for quantifying annoyance. Finally, Section 7.4 discusses specific annoyance questions asked in the studies, and issues arising from differences between the questions asked in different studies.

7.1 Survey Instrument Overview

Table 7-1 provides a summary of the salient features of the various survey instruments. The first column identifies the study. The second and third columns show how the respondents were contacted; one of two modes was used, face-to-face (F/F) or telephone (Tel)[7]. The only exception was the Burbank study, in which the first contact attempt was face-to-face and if unsuccessful followed up by telephone. The number of follow up attempts before dropping the potential respondent from the survey is shown in column three.

The fourth column indicates the espoused purpose of the survey. In general, respondents are often curious about the purpose of the survey. In half of the studies a reason was never offered, and "None" is entered in the column. In the other half of the studies a reason was offered, either during the interviewer's opening remarks or during the survey if the respondent spontaneously asked. In the majority of the studies, the presented purpose had nothing to do with noise or the environment, and "Non-Noise" is entered in the column. Three studies, however, provided explanations citing either the environment in general or the target noise source. In the Minneapolis noise barrier survey, interviewers explained that they were conducting "... a survey for the Minneapolis highway department concerning complaints about the freeway." For the control sites in the 10-Site Traffic Change study survey, two explanations were given. One group was told the survey concerned domestic energy consumption; the other was informed that it concerned the effects of traffic. In the Ohio Highway study, the explanation given was a "study of neighborhood environmental quality."

7.2 Questionnaire Lengths

A concern about survey length (total number of questions asked) is a potential for respondent fatigue or premature interview termination by the respondent. Neither of these concerns were addressed in this study. Studies dealing with interview length effects should be consulted both for integrating past research as well as for designing new surveys. It is important to ensure that *length* is not a major factor in the survey outcome. Studies dealing with the length issue have been performed, although none of the change-in-exposure studies cited in this report appears to have referenced this work.

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[7] "N/A" in the columns of Table 7-1 indicates that the feature could not be ascertained for that study.

In long surveys the placement of key questions about attitudes to noise may be of some interest. Columns 5 and 6 of Table 7-1 show the total number of questions in each survey and the question number regarding annoyance, disturbance, bother, etc. with noise. Out of the 13 studies where the interview length was known, 8 had over 50 questions and 4 had in excess of 100 questions. In this regard, the survey of greatest length is the Roissy study where the aircraft noise question was the 110th out of 160 questions.

7.3 Quantifying Attitudes

Perhaps the most elementary issue regarding attitude quantization is that respondent and investigator alike must be clear on the attitude being solicited. If the question is meant to ask for attitudes towards the noise source itself (ie. non-noise related issues) the phraseology should make that point clear. In contrast, if the question is meant to focus on attitudes or feelings about the *noise* itself, the question should clearly state that fact as well. In the case of aircraft noise studies, the respondent must be clear that the question regards "annoyance to noise," not annoyance to some other attribute about the noise source. Eight out of the eight domestic aircraft noise studies reviewed here were quite specific about aircraft *noise*. This detail cannot be overlooked. A lack of specificity here could invalidate a study.

7.3.1 Single Scale vs. Composite Scale Annoyance Rating

Two basic approaches were used to quantify respondents' attitudes about the target noise source for later correlation with noise dose. In the first method (representing the vast majority of studies) the response to a single, multi-point category scale question was used. In the second method (four studies in all) a composite scale was used, formed by mathematically combining the answers to two or more attitude questions on the survey. The claim was that higher correlations of response with dose could be had from a composite of several questions rather than from any single question alone.

7.3.2 Unipolar vs. Bipolar Scales

In the majority of surveys, a single, multi-point adjective scale was used. The multi-point adjective scale presents the respondent with a limited number of fixed choices for communicating the intensity of their response to a particular question. For example, where a survey asks the extent of bother or annoyance by aircraft noise, the choices might be "not at all," "somewhat," "moderately," "very," "extremely." The respondent chooses one of the five adjectives (a choice midway between scale points is not allowed).

This example illustrates a 5-point, unipolar (UP) scale. All of the U.S. airport studies in this review use this scale. Five response choices are offered, and the scale starts from a position of neutrality ("not at all") and proceeds in one direction (of increasing severity) to the scale end ("extremely"). In a bipolar (BP) scale, neutrality is near the middle of the scale, and the scale reflects increasingly positive attitudes in one direction, and increasingly negative attitudes in the other. An example of such a scale is the satisfaction scale used in two of the studies, the "8-Site Traffic Change" study by

Griffiths and Raw, and the "14-Site Traffic Change" study by Baughan and Huddart (study descriptions may be found in Sections A.2.10 and A.2.11, respectively, of Appendix A). The scale spanned the range from "Definitely Satisfactory" to "Definitely Unsatisfactory." The number of choices in the response scale, and whether it was a unipolar or bipolar scale, is shown in column 7 of Table 7-1.

7.3.3 Target Timeframe Identified

The last column in Table 7-1 shows whether or not each study provided a reference time frame to the respondents, and if so, its length. Note that some studies solicited responses for several different time frames. The results are mixed. Of the 13 surveys where it could be determined, 8 did not specify a reference time frame and 5 did. In the case of the Burbank study, three questions, one right after the other, were identical except for the time frame sought (past week, past month, and past year) for attitudes towards aircraft noise. The responses were distinctly different for the three different time frames, suggesting that people *do* have the ability to focus on specific time frames. This topic is discussed again in Section 7.4.3.

7.4 Specific Annoyance Questions

Tables 7-2, 7-3, and 7-4 list the noise related attitude questions in the surveys for airports, roadways, and railways, respectively. A compendium of the different adjective scales used across all the studies is presented in Table 7-5. This table identifies the number of points on the scale, the exact wording of the scale points, and a cross-reference to studies using the scale. The table is divided into four sections from top to bottom indicating whether the question had to do with annoyance, annoyance and bother together, bother alone, or satisfaction. The satisfaction scale was the only bipolar scale used in the studies reviewed.

Four points are of particular interest in the survey questions on noise:

(1) Was the target noise source specified in the question?
(2) Was a specific setting (indoors, outdoors, etc.) specified in the question?
(3) Was a specific time frame specified in the question?
(4) Was there potential bias in the way the question was phrased or worded?

7.4.1 Specification of Target Noise Specified

In all studies where the noise question could be ascertained, the target noise source was clearly identified. No study failed to incorporate the source in the very sentence asking for an attitude rating on noise.

Table 7-1. Survey Instrument Summary

Study Name	Mode[1]	Call-backs	Espoused Purpose	Survey Length[2]	Annoy Quest[2]	Attitude Scale[3]	Time Period for Consideration
Airport							
Heathrow	F/F	N/A	Non-Noise	118	20	Compos	None
Los Angeles	Tel	N/A	None	37	1	5-pt, UP	None? Past wk?
Roissy	F/F	N/A	Non-Noise	160	110	4-pt, UP	None
Burbank	F/F, T	4	None	4	2	5-pt, UP	1-wk, 1-yr
Orange County	Tel	4	N/A	5	4	5-pt, UP	1-wk, 1-yr
Oslo	Tel	Yes	Non-Noise	110	18	4-pt, UP	None
Atlanta	Tel	4	Non-Noise	11	7	5-pt, UP	1-yr
Bodø/Værnes	Tel	N/A	Non-Noise	94	36	4-pt, UP	1-dy, 4-wks, 6-mos, 1-yr
Roadway							
Huddinge	F/F	N/A	Non-Noise	N/A	N/A	?-pt, N/A	N/A
Heston	F/F	N/A	None	N/A	N/A	9-pt, N/A	N/A
Minneapolis	F/F	4	Freeway	88	10	7-pt, UP	None
Wuppertal/Düs	N/A	N/A	N/A	N/A	N/A	Compos	N/A
10-Site Traffic	F/F	N/A	Traf/Enrgy	30	4	4-pt, UP	None
Ohio Highway	F/F	N/A	Env Qual	>50	N/A	Compos	1-mo
6-City Traffic	N/A	N/A	N/A	N/A	N/A	Compos	N/A
Brisbane Red.	F/F	2	Non-Noise	N/A	1	7-pt, UP	None
Brisbane Incr.	F/F	6	Non-Noise	N/A	N/A	7-pt, UP	None
8-Site Traffic	F/F	N/A	N/A	N/A	N/A	7-pt, BP	None
14-Site Traffic	N/A	N/A	N/A	N/A	N/A	7-pt, BP	N/A
French Barrier	N/A	N/A	N/A	N/A	N/A	5-pt, N/A	N/A
Railway							
Shinkansen	F/F	N/A	N/A	52	28	7-pt, UP	None
Zoetermeer	F/F	N/A	Non-Noise	148	77	4-pt, UP	None

Notes: (1) F/F=Face-to-face, Tel=Telephone, (2) Question number, (3) # of scale points, UP=Unipolar, BP=Bipolar

7.4.2 Specification of Setting Specified

With regard to specifying a situational context in which to consider the noise source, eight unique descriptions were found and are summarized in Table 7-6. The first four are essentially one in the same. They are specific to the extent of being in or around the home, but they are neutral on other issues. Respondents were thus free to integrate for themselves such issues as indoor versus outdoor activities, time of day, amount of time spent at home, etc. The studies using the setting "here" (both Brisbane studies) raise the question of where "here" is, but both were administered face-to-face so there little chance of ambiguity. Five aircraft and three roadway studies are represented in this group.

In contrast, three roadway studies asked respondents to consider an indoor setting only, and one aircraft study (Oslo) asked respondents to consider four different settings: indoors, outdoors, just on weekends, and just during the evening. An open-ended setting (such as one in the first four in the table) was not solicited in this study, however. Finally, in four of the studies no setting whatsoever was specified.

7.4.3 Specification of Time Frame Specified

Table 7-7 summarizes the frequency with which any form of time frame was mentioned in the noise attitude question. In only five studies was a time frame identified. In each of these five, the time frame started at some point in the past and continued to the present. No study asked the respondents to consider an isolated period out of the past that did not include the present. The remaining eleven studies did not specify any time frame.

Fidell (1981) demonstrated the importance of providing survey respondents with a reference time frame in questions regarding aircraft noise exposure, especially where recent changes are involved. He showed that when asked, survey respondents can successfully focus on specific periods of time (past week, past year) and provide meaningful and internally consistent annoyance responses to aircraft noise for different periods of time. This was especially true for the long term ("past year") questions that were asked both before a change and again several times after the change. As time passed after the change annoyance shifted systematically from the pre-change condition towards a new level of annoyance which was consistent in direction with the direction of the noise change.

7.4.4 Potential Bias

Only one noise attitude question was found with the potential for bias, the Minneapolis noise barrier study. The noise question was immediately prefaced by the sentence,

> *I am going to name some of the major objections that some people have about living near freeways.*

The term "major objections" has the potential for bias. Presumably, however, the bias would be the same both before and after the noise change, and should cancel out. There is no way to ascertain the validity of this assumption however. It would simply be safer to avoid this type of language in future studies. In addition to the annoyance question itself, its placement in the questionnaire could cause bias. However, the studies in this review do not alone provide enough information to resolve this issue.

Another potential source of questionnaire bias is the wording of questions preceding the noise annoyance question. This study did not investigate this issue.

Table 7-2. Airport Survey Questions on Annoyance

Study	Survey Question
Heathrow Evolutionary Air Traffic Change	Please look at this scale and tell me how much noise of the aircraft bothers or annoys you: very much, moderately, a little, or not at all. (Respondents were only asked this question if they could hear aircraft, and the response was numerically combined with responses to other questions to form a composite response).
Los Angeles Permanent Night Flight Cessation	Are you ever annoyed by aircraft noise in your neighborhood: not at all, slightly, moderately, very, or extremely?
Roissy New Airport Opening	The airplane noise annoys you: a lot, moderately, a little, or not at all?
Burbank Temporary Runway Closure	While you've been at home over the past (week/year), would you say you've been not at all annoyed by aircraft noise, slightly annoyed by aircraft noise, moderately annoyed by aircraft noise, very annoyed by aircraft noise, or extremely annoyed by aircraft noise?
Orange County Temporary Departure Procedure Changes	While you've been at home during the past week, have you been bothered or annoyed by the noise of large airliners? Would you say you've been slightly annoyed by the noise of large airliners, moderately annoyed, very annoyed, or extremely annoyed by the noise of large airliners?
Atlanta Permanent Noise Insulation	While you've been at home in the past year have you been bothered or annoyed by the noise of airplanes? Would you say you've been slightly annoyed by the noise of airplanes, moderately annoyed, very annoyed, or extremely annoyed by the noise of airplanes?
Bodø/Værnes Temporary Military Exercises	When at home have you heard noise from aircraft the past 4 weeks? Do you consider this noise very annoying, quite annoying, a little annoying, or not annoying?
Oslo Temporary Traffic Increase	Do you hear noise from aircraft inside/outside/on weekends you spend at/during evenings you spend at your home? Do you consider this noise very annoying, quite annoying, a little annoying, or not annoying?

Table 7-3. Roadway Survey Questions on Annoyance

Study	Survey Question
Huddinge New Roadway	Not ascertained
Heston Noise Barrier	Not ascertained
Minneapolis Noise Barrier	I am going to name some of the major objections that some people have about living near freeways. I would like to see how you feel about them. The various possible answers are listed on this card. How do you feel about freeway noise: unobjectionable, somewhat objectionable, moderately objectionable, very objectionable, extremely objectionable, extremely objectionable and intolerable, or absolutely intolerable?
Wuppertal / Düsseldorf	Multi-question composite scale.
10-Site Traffic Decrease	When you are indoors can you hear noise from traffic? Does this bother you very much, quite a lot, not very much, or not at all?
Ohio Highway Opening	Multi-question composite scale.
6-City Traffic Decrease	Multi-question composite scale.
Brisbane Reduction in Traffic	To what extent does traffic noise annoy you here: not at ali, very little, a small amount, a fair amount, quite a bit, a lot, or a great deal?
Brisbane Increase in Traffic	To what extent does traffic noise annoy you here: not at all, very little, a small amount, a fair amount, quite a bit, a lot, or a great deal?
8-Site Traffic Increase and Decrease	How satisfactory do you find the level of traffic noise which you hear when you are in your home? Definitely satisfactory (0). . . Definitely unsatisfactory (6).
14-Site Traffic Increase and Decrease	Not ascertained. Indoors, at home, 7-point satisfaction scale.
French Barrier Construction	Not ascertained

Table 7-4. Railway Survey Questions on Annoyance

Study	Survey Question
Shinkansen	To what extent are you disturbed by railway noise? Not at all (1). . . Very much (7)
Zoetermeer Rail Line Opening	Do you find noise from the Sprinter very annoying, annoying, or not annoying? (Note: respondents were only asked this question if they volunteered that they heard the Sprinter).

Table 7-5. Survey Response Scale Summary

Scale Points	Adjective Scale	Studies
	Annoyance	
7	not at all, very little, a small amount, a fair amount, quite a bit, a lot, a great deal	Brisbane Incr, Brisbane Decr
5	not at all, slightly, moderately, very, extremely	Los Angeles, Orange Cnty, Burbank, Atlanta
4	not at all, a little, moderately, a lot	Roissy
4	not at all, a little, quite a bit, very	Bodø, Oslo
3	not annoying, annoying, very annoying	Zoetermeer
	Annoyance and Bother	
4	not at all, a little, moderately, very much	Heathrow
	Bother	
4	not at all, not very much, quite a lot, very much	10-Site Traffic
	Disturbance	
7	Not at All I . . . I . . . I . . . I . . . I . . . I Very Much	Shinkansen
	Satisfaction	
7	Definitely Satisfactory I . . . I . . . I . . . I . . . I . . . I Definitely Unsatisfactory	8-Site Traffic 14-Site Traffic

Table 7-6. Survey Setting Specification Summary

Setting	No. of Studies	Target Noise
In your neighborhood	1	Aircraft
Here [1]	2	Roadway
At home	4	Aircraft
Living near <target source>	1	Roadway
Subtotal ...	8	
Indoors	3	Roadway
Inside, outside, weekends, evenings [2]	1	Aircraft
Not specified	4	Aircraft (2) Railway (2)

Notes: [1] Face-to-face interview at respondent's residence.
[2] Four separate questions were asked in one survey.

Table 7-7. Survey Time Frame Specification Summary

Time Frame	No. of Studies	Target Noise
Past week	1	Aircraft
Past Month	2	Aircraft
Past Year	2	Aircraft
Subtotal ...	5	
Not specified	11	Aircraft (4) Roadway (5) Railway (2)

Examination of the above tables leads to the following conclusions:

Conclusion: ***All of the studies in this review used response determinations based on respondents' answers to questions concerning annoyance, disturbance, bother, or similar concepts (all referred to as "annoyance" in this review). There is*** *little consistency between the length of surveys, exact placement of the annoyance question, annoyance scale used, or frame of reference specified.*

Conclusion: *Response determinations for all of the U.S. airport studies in this review are based on a 5-point unipolar annoyance scale. Lacking a clear, preferable alternative, this scale should be used in future research in the field. Multiple annoyance questions can be used within a single survey to relate different scales.*

Conclusion: *Whatever the annoyance scale used, annoyance questions should provide a frame of reference: the time over which the respondent should evaluate noise, whether noise heard "at home" or elsewhere should be evaluated, a target source to be evaluated.*

Conclusion: *The studies in this review provide no evidence that the stated purpose of the survey, survey length or placement of the annoyance question in the survey create bias. However, to minimize the possibility of bias, it is recommended that surveys be kept as short as feasible, that annoyance questions be placed early on in the survey, and that no purpose, or a neutral purpose be given as justification for the survey.*

8. ANALYSIS METHODS

This section provides a descriptive summary of the analysis methods and results of the studies in this review. Previously, a meta-analysis has been performed using findings from most of the studies examined in the current review (Fields, 1992). The meta-analysis tested the effect of personal and situational variables on noise annoyance. Of the 26 topics covered in the analysis, 2 relate to change in noise exposure studies. It is beyond the scope of this review to repeat or extend the meta-analysis, but its results are summarized in Section 8.1. The analysis methods used in the change in noise exposure studies are described in Section 8.2. The analysis results pertaining to the abrupt change effect are discussed in Section 8.3, and the analysis results pertaining to the decay of the abrupt change effect are discussed in Section 8.4.

8.1 Summary of the Meta-Analysis Results

The meta-analysis performed by Fields (1992) examined 680 publications from 282 social surveys of residents' reactions to environmental noise. From these, 495 findings were identified relating to 26 topics. A finding was classified as "important" or "not important" based on whether the finding met one of six specific criteria (Fields, 1992, p. 5). Also, the finding was labeled "standard" or "nonstandard" based on the quality of the finding (Fields, 1992, p. 4-6). The two topics relating to a change in noise exposure were expressed in the form of the following hypotheses:

A new noise or change in noise will impact annoyance more than would be predicted from reactions to a familiar, existing noise (Topic 20).

As the time since an increase in noise levels lengthens, annoyance decreases (Topic 21).

Topic 20 tests for the existence of an abrupt change effect. By Fields' analysis criteria, if the stated hypothesis is true then a significant (equivalent to a 3-dB or greater effect by Fields criteria), positive abrupt change effect exists. Topic 21 tests for a decay in the abrupt change effect after an increase in noise exposure (but not after a decrease). If the hypothesis is true, then there is a decay in the change effect following a change.

The result of the meta-analysis is that the evidence is mixed with regard to both topics. There is no clear support of either of the stated hypotheses, although a majority of the standard findings (62% of the findings, 60% of the interviews) support the hypothesis that "respondents over-react to a change." Also, a majority of the standard interviews (but not a majority of the standard findings) support the hypothesis that annoyance decreases after an increase in noise exposure. Table 8-1 summarizes the results of the meta-analysis for Topic 20 (Fields, 1992, p. 204). The results are presented for the combination of standard and non-standard, and for standard findings alone. For the combination and for standard findings alone, the results are given both in terms of the percentages of findings and percentages of interviews. The percentages are given for the findings or interviews that show people under-react to a change, show no important difference, and over-react to a change.

Table 8-1. Summary of Meta-Analysis Results for Reaction to Change, Topic 20

Type of Findings	Findings or Interviews	Number of Findings or Interviews	Percent of Findings or Interviews that Show When the Noise Exposure Changes:		
			Respondents Under-React to a Change	No Important Difference	Respondents Over-React to a Change
Standard & Nonstandard	Findings	19	11%	47%	42%
	Interviews	16,516	34%	35%	32%
Standard Only	Findings	13	8%	31%	62%
	Interviews	8,656	10%	29%	60%

Table 8-2 summarizes the results of the meta-analysis for Topic 21 (Fields, 1992, p. 208). This table is similar to Table 8-2, except the results presented are the percent of findings or interviews that show annoyance increases after an increase in noise exposure, that there is no important difference, and that annoyance decreases after an increase in noise exposure.

Table 8-2. Summary of Meta-Analysis Results Reaction after Change, for Topic 21

Type of Findings	Findings or Interviews	Number of Findings or Interviews	Percent of Findings or Interviews that Show as Time Passes Since an Increase in Noise Exposure:		
			Annoyance Increases	No Important Difference	Annoyance Decreases
Standard & Nonstandard	Findings	7	43%	14%	43%
	Interviews	1,581	13%	38%	49%
Standard Only	Findings	6	33%	17%	50%
	Interviews	1,450	6%	41%	53%

Since the meta-analysis covers only literature published through 1987, several of the newer change in noise exposure studies are not included. These are the Oslo, Atlanta, Bodø/Værnes, 14-Site Traffic Change, and French Barriers studies. However, including these studies in the meta-analysis would be unlikely to change the results. Neither the Oslo or Bodø/Værnes studies showed a positive abrupt change effect, but the 14-Site Traffic Change study did. Neither the Atlanta nor the French Barrier study includes a baseline dose-response curve (the Atlanta study compares the results with the Schultz curve), so it is difficult to interpret the results of these studies. None of these studies address Topic 21, the issue of whether or not annoyance decreases in the time following an increase in noise exposure.

The meta-analysis shows that there is no overall pattern in the results of studies designed to measure an abrupt change effect or the decay of the abrupt change effect. The remainder of this section discusses the analysis methods and results of the studies that may provide some guidance concerning how the studies differ. Recommendations for more in-depth analysis of individual studies and for potential, further research, are presented in Section 10.

8.2 Analysis Methods Used in Prior Work

This section describes the analysis methods used in the reviewed studies. There is a great deal of variation in the degree of complexity that the studies employ in their analysis methods. In several studies, such as the Heathrow, Roissy and barrier studies, testing for an abrupt change effect or a decay of this effect was not the primary goal of the study. As would be expected, analyses of abrupt change-in-exposure issues in these studies was not as extensive as in studies where this effect was the primary issue under investigation. On the other hand, the analysis of the Oslo study is very complete, with dose-response relationships fit using linear, polynomial, and logistic regression, an explicit test of the abrupt change effect, and estimates of the affects of mediating variables. As they relate to measuring the effect of a change in noise exposure, the analysis methods may be grouped in the following three categories, in order of increasing complexity:

Least Complex: Results for annoyance and noise exposure are tabulated by interview areas and round of interviews. Standard deviations or results of significance tests may or may not be presented. There is no derivation of a local baseline dose-response curve, although the results may have been compared with the Schultz Curve in lieu of a local baseline curve.

More Complex: In addition to the data presented for the least complex analyses, the more complex analyses include discussion of the influence of mediating variables, and test for the significance of the results. There may be a derivation of a dose-response curve, but either it is not truly a baseline curve (usually because data from all interview rounds are lumped together) or the sample population underlying the dose-response curve was from an entirely different geographic area from the test population.

Most Complex: The most complex analyses explicitly test for either an abrupt change effect or a decay in the effect. If the test is for an abrupt change effect, then the study includes a baseline dose-response curve (other than the Schultz Curve). Like the more complex analyses, they include a discussion of the influence of mediating variables, and may estimate the size of their effects.

Using this complexity rating scale, Tables 8-3 and 8-4 summarize the level of complexity of the analysis for each study. Table 8-3 summarizes the analysis of the abrupt change effect, and Table 8-4 summarizes the analysis of the decay of the abrupt change effect. The first column lists the name of the study, the next three columns indicate whether the analysis is "least complex," "more complex," or "most complex," in the manner described above, and the last column gives a brief description of the primary analysis method used. Studies with similar analysis methods are grouped together in the tables.

Table 8-3. Analysis Methods for Change Effect Studies

Study	Level of Complexity of Analysis (see p. 68)			Description of Analysis
	Least	More	Most	
Los Angeles	✓			simple comparison of annoyance before and after a change in noise exposure
Atlanta	✓			
Heston	✓			
Brisbane Reduction	✓			
Brisbane Increase	✓			
French Barriers	✓			
Heathrow		✓		comparison of annoyance for 1961 & 1967, careful consideration of mediating variables, derivation of dose-response curves for 1961 and 1967
Shinkansen		✓		derivation of separate dose-response curves for Tokaido and Sanyo lines
Roissy		✓		comparison of round-by-round data, data from all rounds of interviews lumped together to derive a dose-response curve, or to compare with a dose-response curve from another study
Burbank		✓		
Orange County		✓		
Bodø/Værnes		✓		
Minneapolis		✓		
Burbank (Griffiths & Raw reanalysis)			✓	baseline curve from "before" data, comparison with "after" data
Wuppertal/Düsseldorf			✓	derivation of baseline and post-change dose-response curves from data at multiple sites in the study area or similar geographic area
10-Site Traffic Change			✓	
6-City Traffic Change			✓	
8-Site Traffic Change			✓	
14-Site Traffic Change			✓	
Oslo			✓	very complete analysis, careful consideration of abrupt change effect, error analysis, mediating variables

Table 8-4. Analysis Methods for Decay of Change Effect Studies

Study	Level of Complexity of Analysis (see p. 68)			Description of Analysis
	Least	More	Most	
Burbank	✓			simple comparison of annoyance round-by-round
Huddinge	✓			
10-Site Traffic Change	✓			
Brisbane Increase	✓			
8-Site Traffic Change	✓			
Roissy		✓		1977 Charles de Gaulle data plotted on graph with 1975 data and Orly data
Shinkansen		✓		derivation of separate dose-response curves for Tokaido (baseline) and Sanyo (change) lines
Zoetermeer			✓	derivation of dose-response curves by round, comparison of repeat interview data with data for newcomers
Ohio Highway			✓	very complete analysis, careful consideration of error analysis, mediating variables

In analyzing the abrupt change effect, the more complex analyses attempt to control for noise level by using a baseline, long exposure history dose-response curve. As discussed in Section 4.3, the baseline curve can be based on the Schultz Curve (for the least complex analyses), data from other areas without a change in noise exposure, or based on data from the study areas before a change in noise exposure. In analyzing the decay of the change effect, most studies use a simple comparison of annoyance scores for the same area for two different points in time. Assuming the noise exposure remained constant over that time (in some cases it had not), the analysis involves a report of the difference in annoyance and a significance test of the result.

A weakness in the analysis of many of the studies is that they frequently fail to account for the possible influence of mediating variables, such as the specific neighborhoods where interviews were conducted, demographic variables, attitudes and expectations of the respondents concerning the noise source, and other variables. Also, many studies report little or no error analysis, or use error analysis methods applicable to a simple random sample to analyze a clustered sample. However, two studies in particular, the Oslo and Ohio Highway studies, are very thorough in their analysis of mediating variables and in their error analysis, and provide a good starting point for future research.

8.3 Analysis of the Abrupt Change Effect

Although few of the studies in this review provide a decibel-equivalent estimate of the magnitude of the abrupt change effect, in most cases the magnitude of the effect can be estimated from the available literature. Table 8-5 summarizes estimates of the abrupt change effect for each of the studies. The first column of the table lists the study name. The second column lists the average change in noise exposure across the communities surveyed in the study. The third column lists the decibel equivalent abrupt change effect.

The decibel equivalent change affect may be added to the average measured change in exposure to find the typical, effective annoyance change for each study. For instance, in the Bodø/Værnes study a typical change in noise exposure at Bodø Airport was +6 dB. The abrupt change affect was found to be -6 dB, so the effective annoyance change was that expected for a +6-6 = 0 dB exposure change. In other words, the observed annoyance did not change despite a 6 dB increase in noise exposure. In the Heston study, the measured noise exposure was reduced by approximately 4 dB. However, with the change affect of -6 dB, therefore the effective reduction in annoyance was approximately 10 dB.

The change effect was estimated for each study as described below:

Heathrow: The investigators found no significant change in annoyance despite an approximate doubling in the number of flights over a six-year period. The change in exposure is +3 dB, so the change effect is thus -3 dB.

Los Angeles: The investigators found no significant change in annoyance despite a cessation of night flights resulting in a 3 dB reduction in DNL. Thus, the change effect is +3 dB.

Roissy: There were no measurements before the opening of Charles de Gaulle Airport, so the change in exposure is not known. However, contours and surveys were performed after the airport was opened in 1975, and again in 1977. These data were plotted on the same annoyance versus noise exposure graph as the data from Orly, which had been exposed to aircraft noise for a much longer period. The investigators concluded that all of the points fell on the same curve; thus, they observed no abrupt change effect.

Burbank: In the initial analysis the investigators compared the data to the Schultz curve and derived dose-response relationships for the areas with increased noise exposure and the areas with decreased noise exposure. The investigators found no definitive "exposure history-related effects;" thus, the abrupt change effect is 0 dB.

In their reanalysis of the Burbank data, Raw & Griffiths derived a baseline dose-response curve from the first round data only (the interviews conducted before the changes in noise exposure). The curve predicts mean annoyance as a function of DNL. There is likely a great deal of uncertainty in this curve, as it is based on only four data points. Raw and Griffiths compared the change in mean annoyance between different interview rounds to the predicted change in annoyance based on the measured noise exposure change and the baseline dose-response curve; from this they concluded that there was an abrupt change effect in the Burbank data. For this review the dB-equivalent abrupt change effect was estimated for each area by comparing the change in mean annoyance between the first and second round of interviews to the change predicted from the baseline curve.

This study is notable for the large changes in noise exposure measured, including both increases and decreases of 9 dB or more. However, as demonstrated by the above discussion, different methods of analysis can lead to quite different results concerning the observed abrupt change effect. Further analysis using the full data set could help resolve the conflicting interpretations of the study's results.

Orange County: In this study the change in noise exposure was relatively small. No significant change in annoyance or abrupt change effect was observed. The investigators derived a dose-response curve using the Orange County data (results for each area and round of interviews), Burbank data, and data from another study at Westchester Airport (Fidell, et al: 1985).

Oslo: In this study the investigators derived separate dose-response curves for the two rounds of interviews, one before and one after the change in noise exposure. The curves were not significantly different, indicating there was no observable abrupt change effect. However, the change in noise exposure was relatively small, typically 3 dB or less.

This study is notable for the fact that individual respondents were assigned noise doses. Also, a large number of mediating variables were recorded for each respondent. The investigators recommend that logistic regression be used to further test for an abrupt change effect, such as is recommended in Section 10 for any future work.

Atlanta: The investigators compared residents with and without sound insulation living near the airport. The difference in noise exposure between the two groups was estimated to be 5 dB. In their analysis, the investigators divided the respondents into 4 categories based on noise exposure (not including the 5-dB adjustment for sound insulation). The percentage of respondents with and without sound insulation who were highly annoyed was plotted on a bar graph separately for each category. In individual noise exposure categories there were differences between respondents with and without sound insulation, but the investigators concluded they could find no significant, overall difference.

For this review an abrupt change effect was estimated by comparing the difference between the respondents in the three categories with the highest exposure (there were very few respondents with sound insulation in the fourth category). Approximately 49.6% of the respondents in these three categories without sound insulation were highly annoyed, compared to 43.2% of the people with sound exposure, a difference of 6.4%. This difference is less than the approximately 8.4% difference predicted using the Schultz curve as a baseline. Thus, using the Schultz curve as a baseline, the estimated abrupt change effect is +1 dB. This estimate should be considered very approximate.

Bodø/Værnes: The investigators estimated the increase in noise exposure during military aircraft exercises was +6 dB at Bodø and +3 dB at Værnes. In graphing the annoyance measured at each airport for each round of interviews, the investigators found no significant difference in annoyance at either airport during the periods of increased exposure. The abrupt change effect is thus -6 dB for Bodø and -3 dB for Værnes.

This study is notable for the large amount of data collected at the two airports. However, unlike the Oslo study, performed by many of the same investigators, this study does not include the same type of detailed analysis. Further analysis of the data from this study may lead to added insights and possibly to additional interpretations of the results.

Heston: For this study the investigators measured a mean reduction in L10 of approximately 4 dB due to construction of a noise barrier. To estimate an abrupt change effect for this review, the measured reduction in noise exposure was compared to the reduction predicted from first-round measurements in the two areas protected by the barrier. The abrupt change effect is estimated to be -6 dB, but should be considered very approximate.

Minneapolis: For this study the investigators measured a mean reduction in Leq of approximately 5 dB due to construction of a noise barrier. In the analysis the investigators graphed mean annoyance versus noise exposure (using Leq, L10, and other metrics). The same function predicted annoyance as a function of noise exposure both before and after the change; thus, an abrupt change effect of 0 dB was observed.

Wuppertal/Düsseldorf: In this study baseline dose-response curves were presented based on the first round data from seven areas. The baseline curves relate noise exposure to three different composite annoyance scales. Construction of noise barriers reduced the noise exposure in the areas by 3 to 18 dB. The abrupt change effect was estimated for each area by comparing the measured change in annoyance with the change predicted using the baseline curves. Separate estimates were found for each of the three annoyance scales; the result is an average of the three. The results indicate that annoyance was reduced following the change in noise exposure, but not by as much as predicted using the baseline curves.

10-Site Traffic Change: This study involved before and after measurements and interviews at 10 sites, primarily in small towns near which highway bypasses were built. Mackie and Davies published a report summarizing the study, but based their analysis on general nuisance from traffic, not specific to noise annoyance or nuisance. However, Langdon and Griffiths compared the before and after data from six of the ten sites to a baseline curve derived from measurements at eight London suburban sites. The differences between the study's sites and the sites measured for the baseline curve cast some uncertainty on the results. In any case, the abrupt change effect was estimated for each site by comparing the measured change in annoyance with the change predicted using the baseline curve.

6-City Traffic Change: This study involved before and after measurements and interviews at 50 sites in 6 cities where a large traffic reduction program was being conducted. The investigators presented dose-response curves for the before and after interviews. The curves indicate that for the mean reduction of 1 dB between all of the sites, the abrupt change effect is -7 dB. In other words, annoyance was reduced by the equivalent of an 8 dB reduction, based on the baseline dose-response curve.

In their report, the investigators caution that the within-site changes in annoyance are poorly correlated with the change in noise exposure. One figure indicates the change in annoyance as a function of the change in exposure for each site. There is little correlation between the two when viewed in this manner, which led the investigators to hypothesize that it was community expectations regarding the traffic reduction program, and not merely the actual change in exposure, that caused a reduction in annoyance.

Brisbane Reduction: In this study residents along a particular street in Brisbane experienced a 15 dB reduction in noise exposure due to a reduction in traffic from a nearby roadway opening. Measurements were conducted after the change in noise exposure. However, additional measurements were conducted in two areas: one similar to the study area before the change and the similar to the study area after the change. As plotted by the investigators, the results from these three areas show no significant deviation from the Schultz Curve. Thus, using the Schultz Curve as a baseline, no abrupt change effect was observed.

Brisbane Increase: This study involved three sets of measurements of a group of 22 respondents who experienced an increase in noise exposure of approximately 8 dB. The increase was caused by increased traffic volumes. The investigators compared the measurements before and after the change to the Schultz Curve. This comparison indicates an abrupt change effect of 9 dB.

8-Site Traffic Change: In this study measurements and interviews were conducted before and after traffic flow changes at 8 sites in southern England. At 6 sites there were decreases in noise exposure; at 2 sites there were increases. The first round data taken before the changes in noise exposure was used to derive a baseline curve. The investigators derived equations relating the change in mean dissatisfaction to the change in exposure. However, for this review the abrupt change effect for each site was estimated by comparing the measured change in dissatisfaction to the change predicted from the baseline curve.

14-Site Traffic Change: In this study measurements and interviews were conducted before and after traffic flow changes at 14 sites in England. At 10 sites there were decreases in noise exposure; at 4 sites there were increases. A dose-response curve from a recent Transport Research Laboratory (TRL) 35-site study was used as a baseline curve, and compared to the equations the investigators derived for relating the change in mean dissatisfaction to the change in exposure. Since the change in mean dissatisfaction at each site was not listed, the abrupt change effect for each site was estimated using the equations provided. This estimate is very sensitive to the slope of the baseline curve, as discussed below.

French Barriers: For this study the investigators measured a mean reduction in noise exposure of approximately 9 dB due to construction of noise barriers. To estimate an abrupt change effect for this review, the measured reduction in noise exposure was compared to the reduction predicted from the Schultz Curve. The abrupt change effect is estimated to be -9 dB, but should be considered very approximate.

Shinkansen: This study involved measurements along two high speed rail lines, one that had been in operation for 8 years, and a newly-opened line that had been in operation for only 4 months. The investigators derived dose-response curves for each line, and found that, accounting for peak noise levels and the number of operations, residents along the newly-opened line were an equivalent of approximately 10 dB more sensitive to noise from the Shinkansen. However, no measurements were conducted along the newly opened line to document the noise exposure before the

Table 8-5. Estimate of the Abrupt Change Effect

Study	Typical Change in Noise Exposure (dB)	dB-Equivalent Abrupt Change Effect (dB)[1]
Studies with Small (≤3 dB) Noise Exposure Changes		
Heathrow	+3	-3
Los Angeles	-3	+3
Orange County	0	0
6-City Traffic Change	-1	-7
Oslo	+3	0
Studies with High Uncertainty (no baseline curve or suspect cross-sectional comparisons)		
Roissy	DK	0
Atlanta	-5	1
Heston	-4	-6
Minneapolis	-5	0
Brisbane Reduction	-15	0
Brisbane Increase	+8	+9
French Barriers	-9	-9
Shinkansen	DK	+10
Studies with the Most Reliable Estimates		
Burbank	-8 to -17 (decrease) 2 to 9 (increase)	0
Burbank (Raw & Griffiths reanalysis)	-8 to -17 (decrease) +2 to +9 (increase)	-2 to -3 (decrease) -2 to +12 (increase)
Bodø/Værnes	+6 (Bodø) +3 (Værnes)	-6 (Bodø) -3 (Værnes)
Wuppertal/Düsseldorf	-3 to -18	0 to +7
10-Site Traffic Change	-3 to -16	-3 to -12
8-Site Traffic Change	-1 to -15 (decrease) +5 to +15 (increase)	-7 to -17 (decrease) +7 to +8 (increase)
14-Site Traffic Change	0 to -10 (decrease) 0 to +5 (increase)	-14 to -31 (decrease) +11 to +28 (increase)

Note: [1] Add this value to the change in noise exposure to calculate the dB-equivalent change in annoyance.

change, and the investigators did not account for a possible, overall difference in sensitivity between the areas, independent of the change in noise exposure. Thus, the estimate of a 10 dB abrupt change effect should be considered approximate. Figure 8-1 depicts the information from Table 8-5 in graphical form. In this figure, the change in noise exposure for each study is plotted on the horizontal axis and the corresponding estimate of the abrupt change effect is plotted on the vertical axis.

The following points are of interest in interpreting this figure:

- Data points that lie along the horizontal axis (on the line labeled "Baseline") indicate cases in which the baseline dose-response curve for the study correctly estimates the change in annoyance; no abrupt change effect was observed in these cases.

- Data points along the dotted line labeled "No Annoyance Change" indicated cases in which there was change in noise exposure but no change in annoyance.

- Data points in the first and third quadrants of the figure (positive exposure changes and positive effects or negative changes and negative effects) indicate cases in which there was an abrupt change effect, and the effect resulted in a change in annoyance greater than that predicted from the baseline curve.

- Data points in the darkly shaded regions between the solid line ("Baseline") and dashed line ("No Annoyance Change") indicate cases in which there was an abrupt change effect, but the effect resulted in a change in annoyance that was less than that predicted from the baseline curve.

- A data point in the lightly shaded regions labeled "degenerative case" would indicate a case in which an apparently contradictory result was found: either the noise exposure increased and the accompanying annoyance decreased, or the noise exposure decreased and the accompanying annoyance increased. No observed data points lie in these two regions.

- In studies where different effects were estimated for different sites or study areas, one data point is shown for each site. This includes the Burbank study (4 points), the reanalysis of the Burbank study (4 points), the Bodø/Værnes study (2 points), the Wuppertal/Düsseldorf study (7 points), 10-Site Traffic Change study (6 points), 8-Site Traffic Change study (8 points), and 14-Site Traffic Change study (14 points).

- Only one point is plotted for the 6-City Traffic Change, since separate results were not given for each of the 50 sites in the study.

- No points plotted for the Roissy and Shinkansen studies because the change in noise exposure is not known.

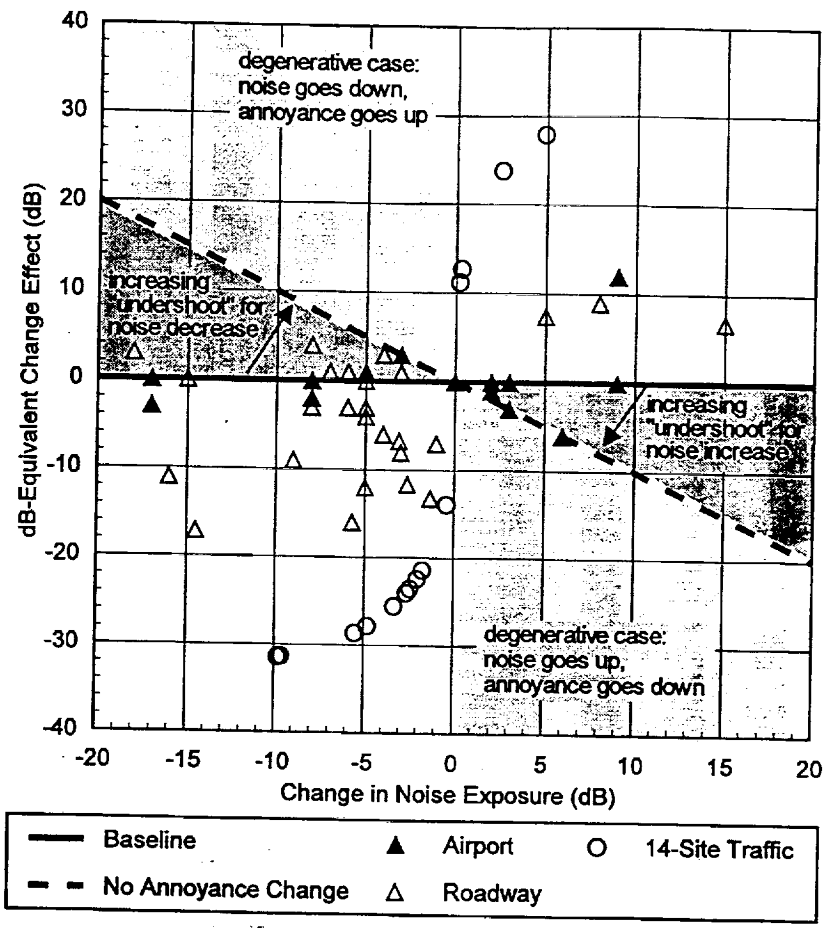

Figure 8-1. Estimates of the Abrupt Change Effect

The results of one study, the 14-Site Traffic Change study, are significantly different from the others shown in the figure; specifically, the size of the effect is much greater than that observed in any other study. However, this result is largely a consequence of the baseline curve used as a basis of comparison with the results from the 14 sites. The 35-site baseline curve, which relates 18-hour L_{10} to mean dissatisfaction on a 7-point scale, is shown in Figure 8-2. The horizontal axis of the figure shows the change in 18-hour L10, and the vertical axis shows the corresponding change in mean dissatisfaction.

Also shown in this figure is the curve derived from the sites in the 14-site study, the baseline curve from the 8-Site Traffic Change study, and the baseline curve from the reanalysis of the Burbank study. The baseline curve from the 8-Site study is directly comparable to that from the 35 site study. The curve from the Burbank study is for annoyance rather than dissatisfaction, DNL rather than 18-hour L10, and has been re-scaled. Despite this manipulation, it has been included to provide a rough comparison of roadway and airport results.

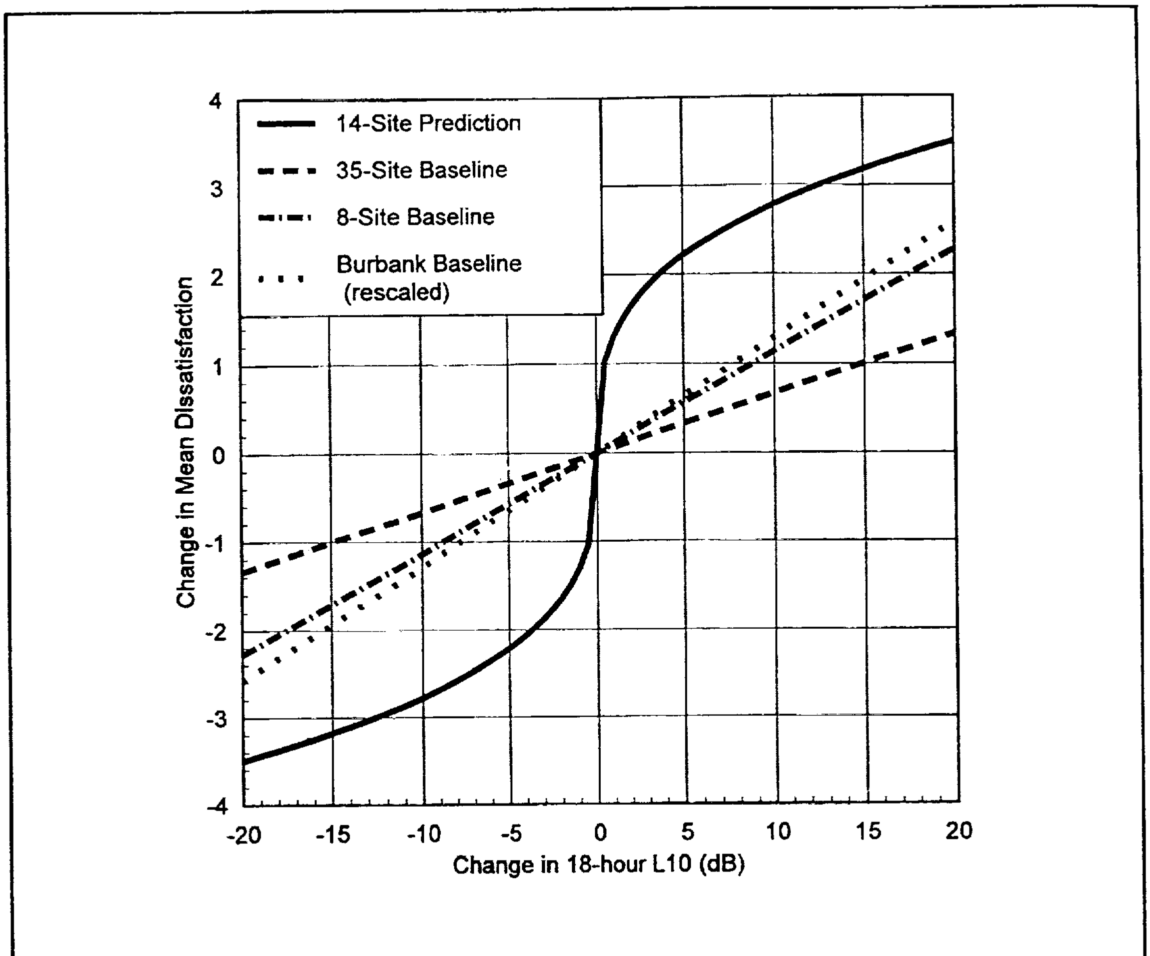

Figure 8-2. Baseline Curves Applicable to the 14-Site Traffic Study

Clearly, the slope of the 35-Site curve (change in mean dissatisfaction/change in L10) is much less than the slope of the 8-Site baseline curve or the Burbank baseline curve. The 35-Site curve has a slope of 0.06, compared to 0.114 for the 8-Site baseline, and 0.129 for the Burbank baseline. A report documenting the 35-Site curve has not yet been published, so it is difficult to interpret the cause of this difference. Figure 8-3 shows the same data as Figure 8-1, except the 14-Site data is recalculated using the 8-Site baseline curve. This seems a reasonable substitution, given the commonality between the two studies. With this adjustment, the 14-Site data compares well with data from other roadway studies.

The following conclusions may be made concerning the analysis of the abrupt change effect:

Conclusion: ***It is possible to estimate an abrupt change effect for most of the studies in this review using the available literature. However, these estimates should be considered very approximate.***

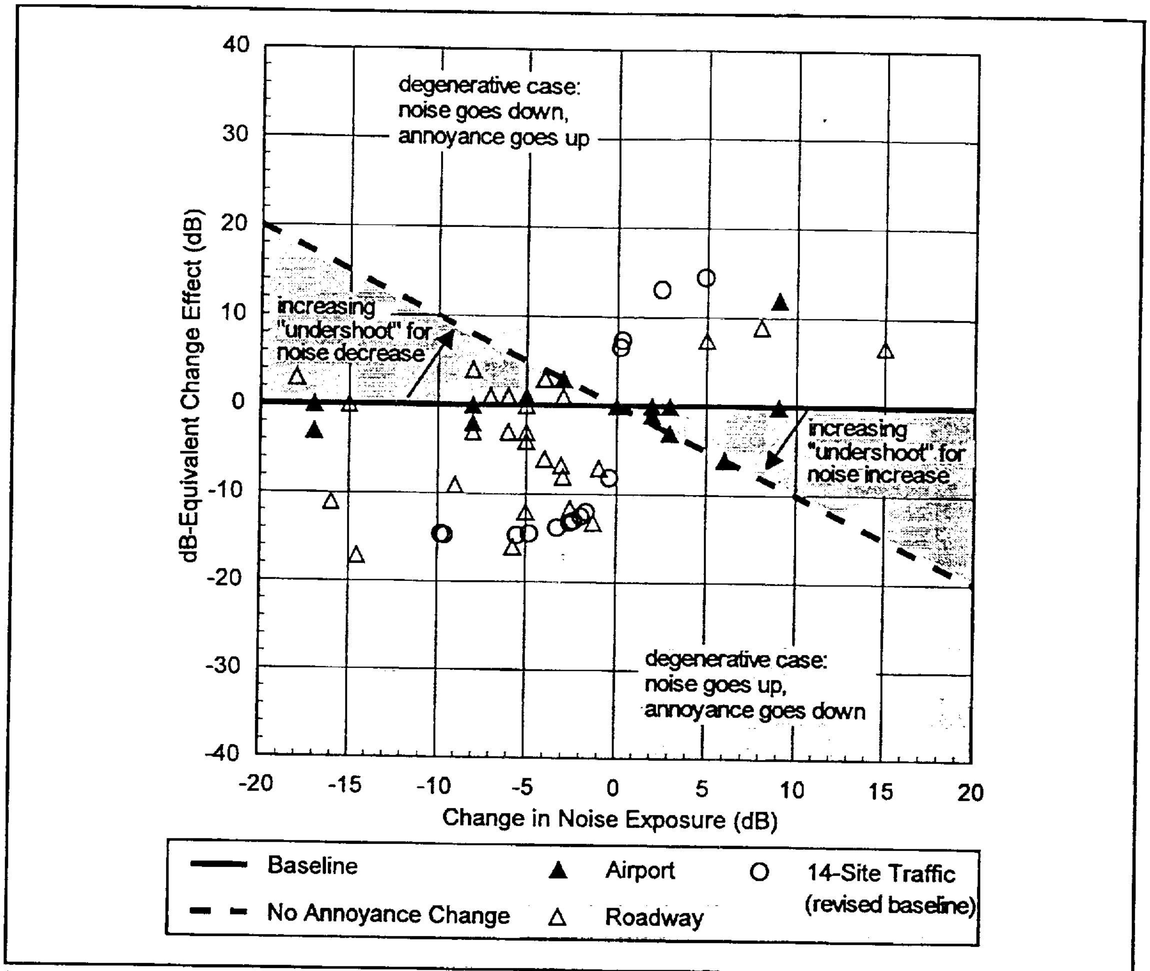

Figure 8-3. Revised Estimates of the Abrupt Change Effect

Conclusion: ***Most of the roadway data in this review indicates that the change in annoyance following a change in noise exposure is greater than the change predicted using a baseline dose-response relationship.***

Conclusion: ***Most of the airport data in this review indicates little or no abrupt change effect. Only in the Burbank study is there an indication of an effect that causes a greater change in annoyance than the change predicted using a baseline curve. However, all of the airport studies either involved temporary changes in noise exposure (Burbank, Orange County, Oslo, Bodø/Værnes), involved small changes (3 dB or less) in noise exposure (Heathrow, Los Angeles, Orange County, Oslo), or had methodological problems that cast significant doubt on the results (Roissy, Atlanta).***

Conclusion: ***Careful analysis of the data from studies that are most recent or that measured the largest changes in exposure, could help put more accurate bounds on the***

range of the abrupt change effect. These include the Burbank, Bodø/Værnes, Oslo, and 14-Site Traffic Change studies.

8.4 Analysis of the Decay of the Abrupt Change Effect

The analyses of the decay of the abrupt change effect that appear in the reviewed studies are typically simpler than the analyses of the change effect. In many cases it is an easier effect for which to test; if the noise exposure remains constant after an increase or decrease in noise exposure, then it is possible to measure annoyance at two different periods following a change and test to see whether annoyance has changed between the two rounds of interviews (so long as time frames are clearly specified for the respondent that identify periods *after* the change).

The Burbank, Huddinge, 10-Site Traffic Change, Brisbane Increase, and 8-Site Traffic Change involve the straightforward form of analysis described above. Of these, the Burbank study involved temporary changes in noise exposure, and the "past week" annoyance responses followed the "past week" exposure quite well with no clear pattern of a decay in any abrupt change effect. The longer period ("past month" and "past year") annoyance responses in this study did show a measurable decay or increase in annoyance (depending on the direction of the noise change). In these survey questions, the requested integration period intentionally overlapped the date of the exposure change as a means for determining whether respondents were taking the specified period into account.

The Roissy, Shinkansen and Zoetermeer studies are somewhat more complex in that these studies involve the derivation of a baseline dose-response curve, and compare data from different rounds to the curve, thus controlling for noise level. Of these, the Shinkansen study is somewhat unique because the it compares results for two different rail lines in different cities; there may be other causes for the differences between the two lines. The Roissy study used a baseline derived at another airport from the one that underwent a change, although the test for a decay of the change effect was made essentially using data from one airport only. The Ohio Highway study includes a careful examination of mediating variables such as community attitudes and the amount of publicity the noise source received prior to each round of interviews, and includes groups of respondents interviewed only once for comparison with the group re-interviewed each round.

Table 8-6 summarizes the results of the analysis of each study. The first column of the table lists the study name. The second column lists whether the change in noise exposure was an increase or decrease. The next two columns give the timing relative to the exposure change of the first and last post-change interviews. The last column summarizes whether or not a decay of the change effect was observed.

As indicated in the table, only the two railway studies concluded that there was a decay of the change effect. Both of these studies involved a new source (as did the Ohio Highway and Roissy studies), rather than a change in an existing source. Except for the Burbank study, none of the studies involved interviews less than 3 months after the change in noise exposure; it is thus possible that some decay of the change effect occurs immediately following a change.

Table 8-6. Estimate of the Decay of the Change Effect

Study	Increase or Decrease In Noise Exposure	Timing of Interviews Relative to the Change In Exposure (months after change)		Decay of Change Effect Observed?
		First Post-Change	Last Post-Change	
Roissy	increase	12	32	no
Burbank	both	0.5	16	inconclusive
Huddinge	increase	6	18	no
10-Site Traffic Change	both (decreases at most sites)	5	96	somewhat
Ohio Highway	increase	4	16	no
Brisbane Increase	increase	7	20	no
8-Site Traffic Change	both (decreases at most sites)	3	20	no
Shinkansen	increase	4	96[1]	yes
Zoetermeer	increase	4	18	yes

Notes: [1] cross-sectional comparison

Conclusion: ***The studies in this review designed to measure the decay of the change effect (called either adaptation or habituation in most of the studies) have generally failed to find a decay of the effect. No study has found a decay of the abrupt change effect at residences near an airport.***

Conclusion: ***Only one study, the Burbank study, which involved temporary noise exposure changes, has measured for the decay of the change effect fewer than 3 months following a noise exposure change. It is possible that a change effect occurs and then decays in the days or weeks immediately following an abrupt change in noise exposure.***

9. GENERAL FINDINGS AND CONCLUSIONS

9.1 General Findings

The 22 studies in this review were all generally successful in establishing the existence of a relationship between noise exposure and annoyance. That is, the study areas in each study provided a range of exposures large enough to illustrate clear correlations between annoyance and exposure. However, in some studies there were only small noise exposure changes in any particular neighborhood, and no measurable change in annoyance. Six studies provided sufficient information for estimating the magnitude of the abrupt change effect. Of these six, three indicated an overreaction to changes in noise exposure (annoyance change more than predicted from a baseline dose-response curve). In these three studies, the investigators specifically tested for the abrupt change effect, paying attention to both the baseline curve and the differences between the baseline and the change in exposure data. All three of these were multi-site roadway studies conducted in Great Britain, and consisted predominantly of sites experiencing a *decrease* in noise exposure.

Two of the six studies indicated an under-reaction to changes in noise exposure. In one, the change in response was in the right direction, but was not as large a change as predicted from the baseline. The other indicated no change in response for a temporary increase in noise exposure of 3 to 6 dB. The results for the last study of the six, the Burbank study, are inconclusive based on the data analyses and interpretations made to date.

Whereas the multi-site roadway studies have tended to show an abrupt change effect for permanent noise exposure decreases, there is no comparable trend in the aircraft studies, even for a comparable magnitude of change. Two possible explanations for this difference are (1) that most of the airport studies have involved temporary rather than permanent changes, and (2) that the day-to-day variability of noise exposure near airports is generally greater than that near roadways, and is often comparable to the exposure change under study. If the abrupt change effect is threshold triggered by an increase or decrease in noise exposure that is noticeably louder or quieter than prior conditions, then the threshold may be higher for airport noise than roadway noise.

With regard to measuring changes in response following a change in noise exposure, termed "decay of the abrupt change effect" in this document, and "adaptation" or "habituation" elsewhere, the evidence supporting this phenomenon is inconclusive. No airport study in this review indicated a decay of the abrupt change effect. The two railway studies did show that annoyance decreased following the opening of a new rail line, but one of these studies was of a questionable, cross-sectional design.

The lack of conclusive evidence supporting either the abrupt change effect or its decay in the time following a change highlights the need for secondary analysis of existing data. It also underscores the need for collection of new data under carefully-considered situations using an equally carefully-designed data acquisition and analysis program.

9.2 Summary of Conclusions

Conclusions from Section 4:

Conclusion: *Of the 22 studies examined in this review, 13 were designed to measure the initial effect of a noise exposure change, 3 were designed to measure the decay of the change effect, and 6 were designed to measure both.*

Conclusion: *Longitudinal sets of interviews, or longitudinal sets of interviews at a cross-section of areas, are a desirable element in the design of change in noise exposure studies. It is difficult to base any conclusions regarding the affect of a change in noise exposure on studies with a cross-sectional design and without longitudinal sets of interviews (this includes the Atlanta, Brisbane Reduction and Shinkansen studies).*

Conclusion: *To measure the abrupt change effect, a study must include an estimate of the baseline dose-response curves. The baseline may be based on the Schultz curve, or derived using either data from other study areas comparable to the areas interviewed in the study (but without a change in noise exposure), or data taken before a change in noise exposure. Most of the studies in this review have some form of baseline dose-response curve.*

Conclusion: *With the exception of the Heathrow study, the studies in this review involve noise exposure changes that occurred over a relatively short period. Typically the change occurred over a few days or weeks, compared to a gradual change over 6 years in the case of the Heathrow study.*

Conclusion: *In the longitudinal studies, the time from the change in noise exposure to the first "after" interview varies from approximately 2 weeks (Burbank, Orange County, Bodø/Værnes) to 12 months (Roissy) after the initial change in noise exposure. Thus, these studies could not measure the abrupt change effect in the event that it occurs and then decays within a few days after a change in noise exposure.*

Conclusion: *The studies that measured the decay of the change effect typically compared responses measured at least 2 months after a change to responses measured a least 15 months after a change.*

Conclusion: *If a change in noise exposure study involves re-interviewing the same respondents, there exists the possibility that the first interview will create a bias in the respondent's subsequent interviews. Separate groups of respondents interviewed only once can be used to test for such bias.*

Conclusion: *The studies in this review typically involved 2 to 3 rounds of interviews with 400 to 5,700 total interviews. Most of the studies in this review involved some form of repeat interviewing. In some studies the investigators purposefully avoided re-interviewing the same individuals. Future studies should use some combination of repeat and non-repeat interviewing.*

Conclusions from Section 5:

Conclusion: *The predominant acoustic dose in the airport studies is DNL. In the roadway and railway studies 24-hour Leq and 18-hour L10 are the predominant acoustic doses.*

Conclusions from Section 6:

Conclusion: *Most of the studies in this review at least tabulate values for certain mediating variables involving demographics and residents' attitudes and expectations. Only the Oslo and Ohio Highway study attempt a complete analysis of mediating variables, including calculating the uncertainty introduced by a clustered sample (Oslo study) or estimating the dB-equivalent effects of mediating variables.*

Conclusion: *Specific study areas/sites, residents' length of residence, attitudes and expectations, and seasonal variations are frequently confounded with changes in noise exposure. The problems introduced by these potentially confounding variables are not intractable, but should be carefully considered in study designs of any future research.*

Conclusion: *Attitudes and expectations, in particular, should be carefully considered in future research. If possible, the concept of "critical tendencies," as discussed in the Ohio Highway study, should be used to explore differences between study areas and to reduce the scatter in dose-response relationships. The causality of annoyance and attitudes should be carefully examined.*

Conclusions from Section 7:

Conclusion: *All of the studies in this review used response determinations based on respondents' answers to questions concerning annoyance, disturbance, bother, or similar concepts (all referred to as "annoyance" in this review). There is little consistency between the length of surveys, exact placement of the annoyance question, annoyance scale used, or frame of reference specified.*

Conclusion: *Response determinations for all of the U.S. airport studies in this review are based on a 5-point unipolar annoyance scale. Lacking a clear, preferable alternative, this scale should be used in future research in the field. Multiple annoyance questions can be used within a survey can be used to relate different scales.*

Conclusion: *Whatever the annoyance scale used, annoyance questions should provide a frame of reference: the time over which the respondent should evaluate noise, whether noise heard "at home" or elsewhere should be evaluated, a target source to be evaluated.*

Conclusion: *The studies in this review provide no evidence that the stated purpose of the survey, survey length or placement of the annoyance question in the survey create bias. However, to minimize the possibility of bias (or increasing unexplained response variance for that matter), it is recommended that surveys be kept as short as feasible, that annoyance questions be placed early on in the survey, and that no purpose, or a neutral purpose be given as justification for the survey.*

Conclusions from Section 8:

Conclusion: *It is possible to estimate an abrupt change effect for most of the studies in this review using the available literature. However, these estimates should be considered very approximate.*

Conclusion: *Most of the roadway data in this review indicate that the change in annoyance following a change in noise exposure is greater than the change predicted using a baseline dose-response relationship.*

Conclusion: *Most of the airport data in this review indicate little or no abrupt change effect. Only in the Burbank study is there an indication of an effect that causes a greater change in annoyance than the change predicted using a baseline curve. However, all of the airport studies either involved temporary changes in noise exposure (Burbank, Orange County, Oslo, Bodø/Værnes), involved small changes (3 dB or less) in noise exposure (Heathrow, Los Angeles, Orange County, Oslo), or had methodological problems that cast significant doubt on the results (Roissy, Atlanta).*

Conclusion: *Careful analysis of the data from studies that are most recent or that measured the largest changes in exposure, could help put more accurate bounds on the range of the abrupt change effect. These include the Burbank, Bodø/Værnes, Oslo, and 14-Site Traffic Change studies.*

Conclusion: ***The studies in this review designed to measure the decay of the change effect (called either adaptation or habituation in most of the studies) have generally failed to find a decay of the effect. No study has found a decay of the abrupt change effect at residences near an airport.***

Conclusion: ***Only one study, the Burbank study, which involved temporary noise exposure changes, has measured for the decay of the change effect fewer than 3 months following a noise exposure change. It is possible that a change effect occurs and then decays in the days or weeks immediately following an abrupt change in noise exposure.***

10. RECOMMENDATIONS FOR FURTHER RESEARCH

This section contains recommendations for three phases of further research: (1) secondary analysis of prior data, (2) collection of new data, and (3) analysis of the combined prior/new data sets. The recommendations address the literature review's two principal questions:

- How large is the immediate abrupt-change effect due to aircraft noise around airports?
- How quickly does this abrupt-change effect decay over time?

Based on the results of the literature review, we must be prepared for a small abrupt-change effect and its associated decay in an airport setting. For that reason, the research must include large quantities of data and a very careful analysis of measurement uncertainties, to determine if measured effects are real or simply due to chance alone.

In addition, the recommended research addresses the following supplemental questions:

- What are the response uncertainties associated with the inferred abrupt-change effect and its decay rate? Stated another way, (1) how will the response uncertainties be translated to an equivalent uncertainty in dose change (in decibels) and (2) can an ample sample size be achieved to reduce the standard error of the mean to a level below the magnitude of the expected effect? This analysis is important to follow-on studies so that valuable resources are not wasted looking for small (1 or 2 decibel) change effects.
- What non-acoustic (mediating) factors influence the abrupt-change effect and its decay? How large is the influence of these factors and what is the variance?
- How can the abrupt-change effect be generalized to airports other than those studied to date?
- How does the abrupt-change effect depend upon whether aircraft noise is part of the "before" noise climate?

This section of the report is organized as follows:

Section 10.1	Desired format of research results
Section 10.2	Expected use of results
Section 10.3	Recommended secondary analysis of prior data
Section 10.4	Recommended collection of new data
Section 10.5	Recommended analysis of the combined data sets

Further details of the recommended analysis appear in Appendix B.

10.1 Desired Format of Research Results

Figure 10-1 shows the desired format of the research's dose-response results. Both graphs in the figure contain a family of dose-response curves: a central baseline curve flanked by a set of abrupt-change curves for different amounts of change, both positive and negative. The dose in both graphs is the same: aircraft DNL, plotted along the horizontal axis. The response differs for the two graphs, however. The top graph relates DNL to mean annoyance while the bottom graph relates it to the percentage of people highly annoyed (in this case, the top two categories of a five-point scale). In each graph, the baseline curve shows the dose-response relationship in the absence of abrupt changes in noise climate. At an airport where the noise climate has been relatively steady over several years, or where it has changed gradually over time, the baseline curve predicts neighbor response as a function of outdoor aircraft DNL. This baseline curve is directly analogous to the Schultz/Fidell dose-response curve, except that it is specific to a particular airport rather than an average over many airports. The specific airport appears in the dose-response title, to emphasize this fact. The recommended research will determine the slope/shape of this baseline curve, plus the curve's horizontal position for each studied airport. In addition, the research will suggest how to reposition this baseline curve horizontally for other airports not yet studied.

Flanking the baseline curve are a series of abrupt-change curves for different amounts of change, both positive and negative. These curves incorporate the abrupt-change effect, which will also be determined through the recommended research.

These abrupt-change curves are explained through the following example (see Figure 10-2). Before an abrupt change occurs, the DNL at some community location is 50 dB. This DNL predicts a mean annoyance of 1.3, per the baseline curve. Then the DNL changes abruptly from 50 dB to 60 dB, an increase of 10 decibels. The mean annoyance after the change is 2.9, per the +10 dB abrupt-change curve. The increase in mean annoyance derives from two portions: (1) an increase from 1.3 to 2.2, sliding up the baseline curve by 10 dB, and then (2) an additional increase from 2.2 to 2.9, rising vertically from the baseline curve to the +10 dB curve. The first portion would occur even with a very gradual DNL increase, and is consistent with annoyance in neighborhoods originally at 60 dB. The second portion, however, is due solely to the abruptness of the increase. It is the abrupt-change effect.[8]

[8] Note that there are two independent variables involved: the initial DNL and the magnitude of the abrupt change, ΔL. We believe that attempts to plot these two independent variables with a single dose-response curve cannot be successful, because a single curve has only one independent variable, DNL.

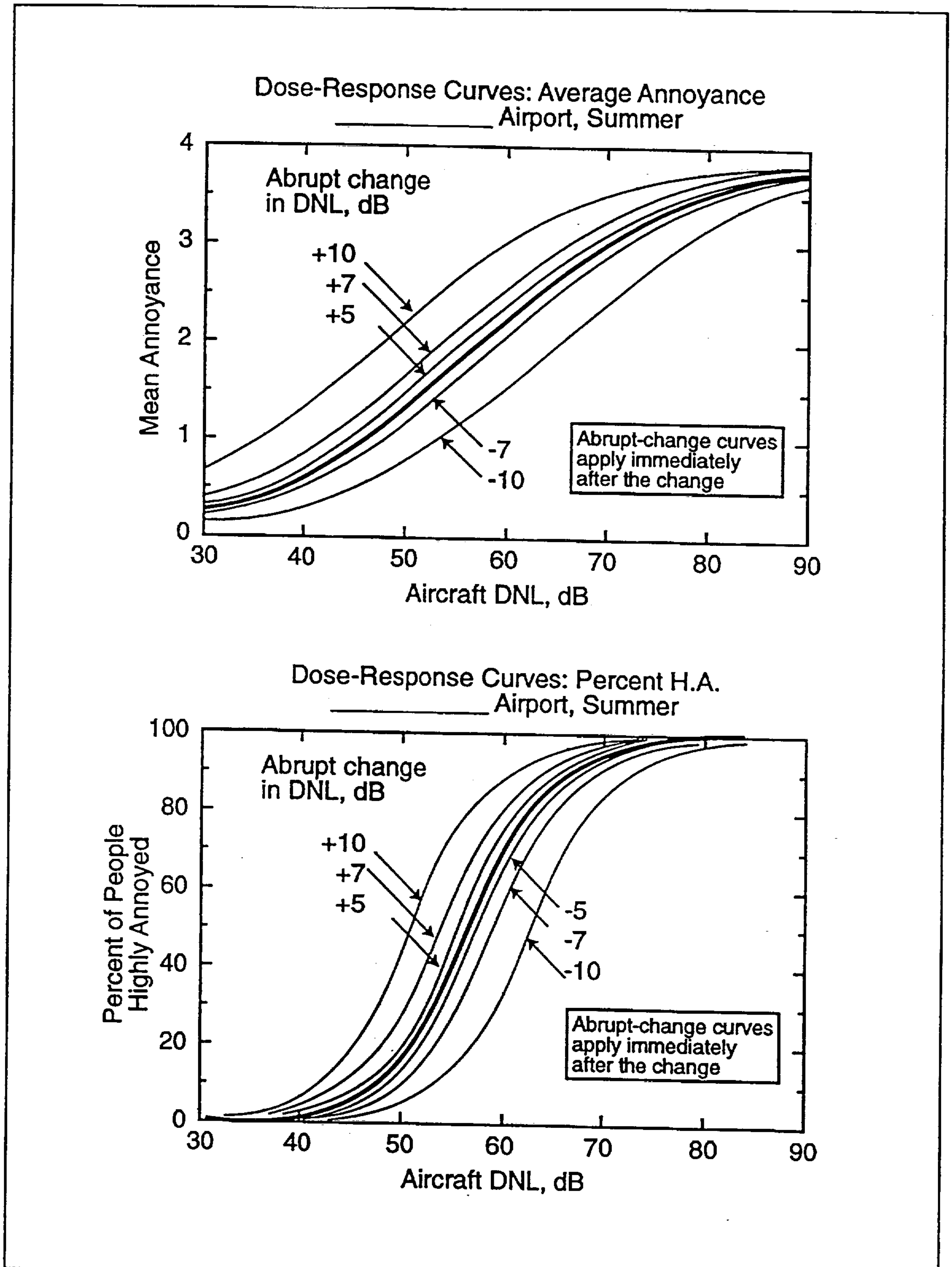

Figure 10-1. Desired Format of the Research Results

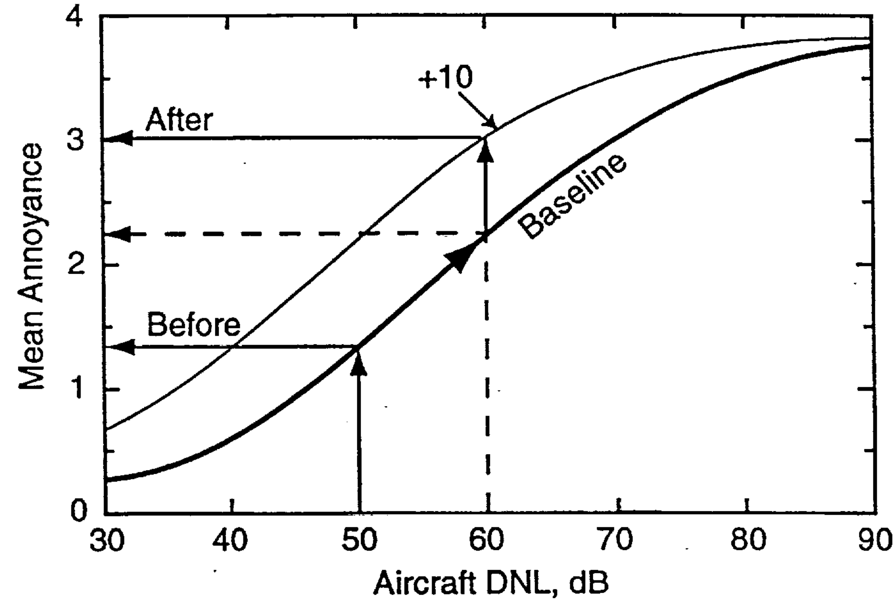

Figure 10-2. Example Use of a Family of Dose-Response Curves

Note that the abrupt-change curves in the figure are not spaced equally around the baseline curve. For example, the seven-decibel spacing between the baseline and the -7 dB curve is very small, whereas the three-decibel spacing between the -7 and -10 dB curves is relatively much larger. This unequal spacing is expected from the research regression, wherein a better fit to the data is expected with a non-linear dependence upon ΔL.

Mediating factors. Each of these families of dose-response curves may be accompanied by an adjustment table of mediating factors: those factors found to be significant during regression analysis. Without adjustment, the family of curves applies to one specific value of each mediating factor. For other values, the table allows adjustment of the aircraft DNL dose to account for the mitigator's effect. Such a dose-adjustment table is possible because the regression relates changes in mediating factors directly to their equivalent changes in aircraft DNL. This technique was shown to be successful in recent dose-response studies for the National Park Service (HMMH, 1993).

Two different sets of mediating factors are conceptually possible: (1) a complete set of factors intended for best scientific understanding, and (2) a reduced set of factors intended for practical use. This reduced set of mediating factors includes only those that are normally feasible to determine during use of the dose-response at other airports. Recommended is the development of dose-response curves with such a reduced set of factors, but also the retention of all data so that later analysis might uncover further scientific relationships.

Confidence Intervals on these curves. The recommended research would also result in measured confidence intervals on these dose-response curves and on the parameters that underlie them. The left panel of Figure 10-3 shows 95-percent confidence intervals on a baseline regression curve. For any given value of aircraft DNL on the horizontal axis, these confidence interval bounds show the range of possible annoyance vertically, with 95-percent certainty.

The right panel of the figure shows corresponding confidence intervals for the +10 dB abrupt-change curve. This abrupt-change curve is located 5 dB horizontally to the left of the baseline curve. In other words, the +10 dB abrupt-change effect is equivalent to an additional 5 dB of dose (in addition to the actual 10 dB increase in dose). The figure shows confidence intervals on this +5 horizontal shift: between +1 and +12 dB.

Note that confidence intervals such as these indicate whether an abrupt-change effect has truly been measured, or whether the apparent effect is possibly due to chance. In the sketch, the effect is "real" with 95-percent certainty because its confidence interval range does not include the value of zero.

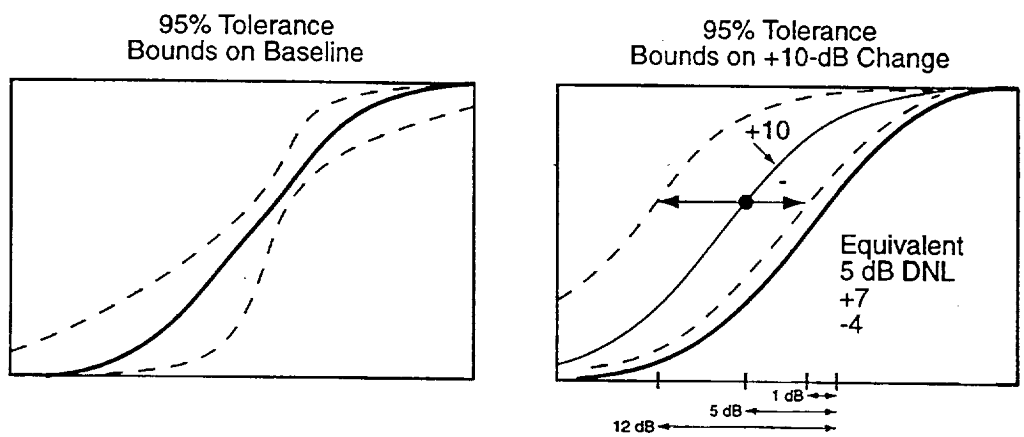

Figure 10-3. Sketch of Measurement Confidence Intervals

Possible variations in shape. The dose-response curves that evolve from the recommended research may have shapes somewhat modified from those in Figure 10-1. Some possible shapes appear in Figure 10-4. The upper-left panel shows a possible linear dependence upon ΔL, for which the abrupt-change curves are equally spaced around the baseline curve. The upper-right panel shows a possible interaction between aircraft DNL and abrupt change. Such an interaction means that the abrupt-change effect is not constant with aircraft DNL, but decreases for higher DNL values, as shown.

The middle two panels in Figure 10-4 show possible skewness in the dose-response curves. The lower two panels show a possible non-zero lower limit and a possible non-saturated upper limit. A non-zero lower limit would result if some respondents are annoyed no matter how low the aircraft DNL. Such respondents might be called chronically annoyed. A non-saturated upper limit would result if some respondents are never annoyed, no matter how high the aircraft DNL. Such respondents might be called imperturbable.

In addition, the analysis will test for significant differences between two other groups of respondents: "repeat" and "non-repeat" respondents. "Repeat" respondents are chosen randomly for a "panel" study, in which the same group of people are questioned both before and after the DNL change -- and possibly also several additional times after the change. "Non-repeat" respondents are chosen randomly for each round of questionnaires. If differences prove not to be statistically significant, then "repeat" and "non-repeat" respondents will be combined into one data set. If differences are significant, separate dose-response families will be developed for each.

Similarly, one other parameter may result in either combined or separate dose-response families: whether or not the "before" DNL was dominated by aircraft. Where it was, then the curves would relate to abrupt increases in aircraft DNL at an airport. Where not, then they would relate to the abrupt introduction of aircraft noise into a noise climate dominated by other noise sources.

Decay of abrupt-change effect over time. The research would also determine whether or not the abrupt-change effect decays over time. Conceptually, families of curves would be obtained at different time intervals after the abrupt change. If decay occurs, then the family of abrupt-decay curves (see Figure 10-1) would shrink in width over time. This measured decay would also have measurement uncertainties, from the analysis, which would then show whether or not the measured decay was real or due to chance.

10.2 Expected use of research results

As mentioned above, the dose-response curves that evolve from the recommended research will apply to the specific airports that were studied. Unfortunately, the research may not succeed in generalizing its results to all airports: it is likely that not enough airports can be measured with reasonable funding and time constraints. Therefore, use of the research's results at other airports may require calibration of the resulting regression curves, as described here.

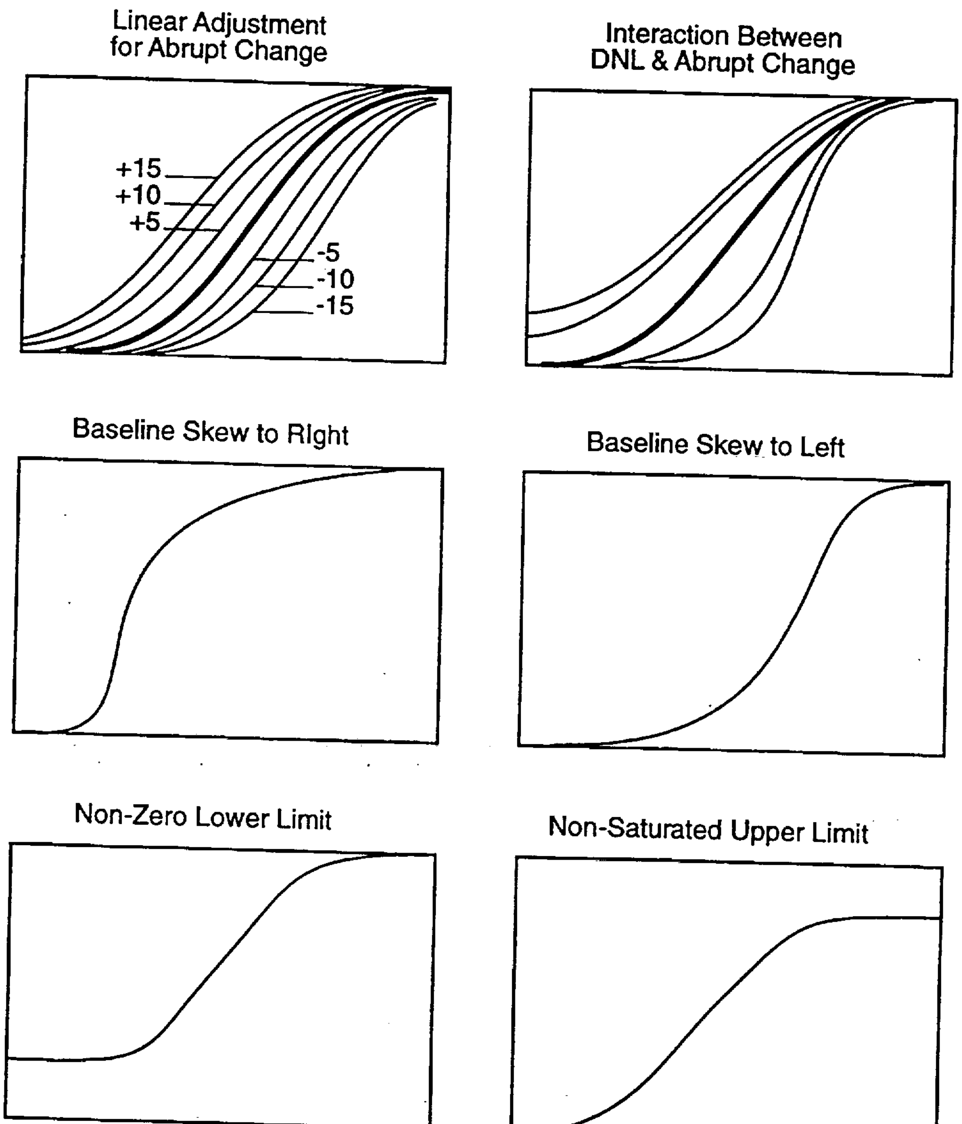

Figure 10-4. Sketches of Other Possible Regression Shapes

First, a baseline dose-response curve must be measured at the new airport, using the methods recommended here. In the analysis of these new-airport data, the regression curve's slope parameter would be forced to be equal to the slope parameter obtained from the full study. The regression would thereby yield the airport's baseline offset from the research airports (in dB). Figure 10-5 shows such an offset. Then the research's relevant dose-response family would be superimposed upon the new airport's baseline, as shown in the figure.

Used in this manner, the new-airport data yield only the new airport's baseline offset, while the full research yields all other aspects of the regression: slope parameter, non-linearity, plus any possible skewness, lower limit and/or upper limit. It is possible that some of these other aspects of the regression may also depend significantly upon specific airport during the research analysis. If so, then some of these other aspects might also have to be calibrated for new airports, if their omission results in unacceptable uncertainty of prediction.

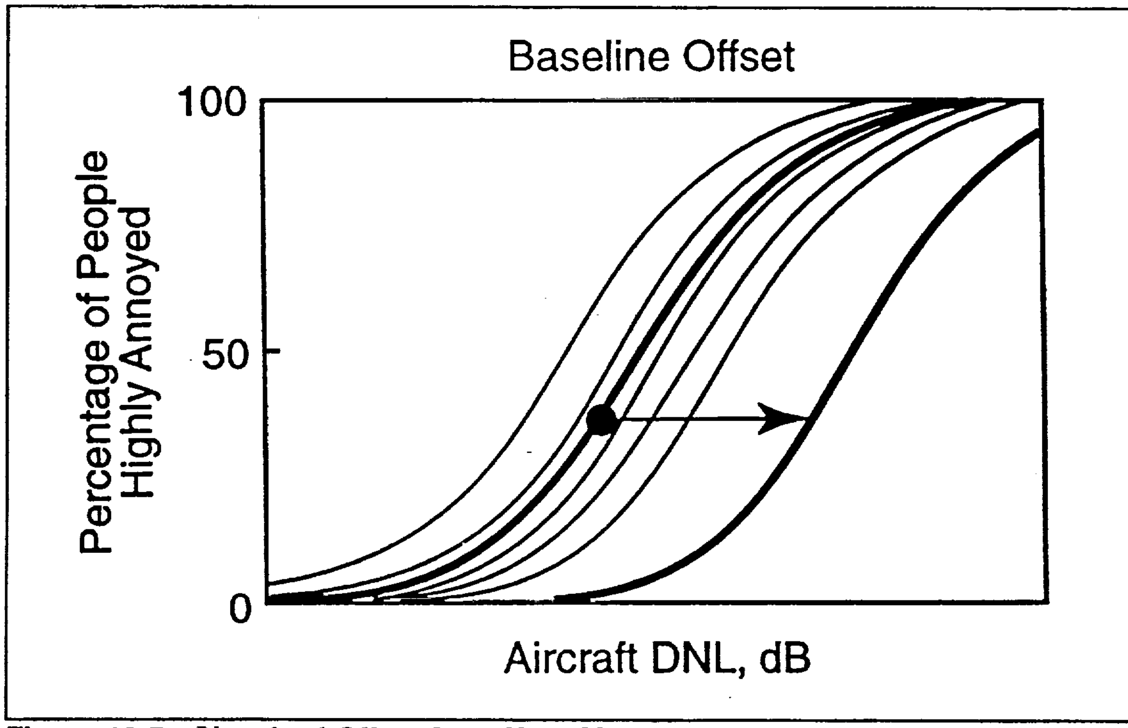

Figure 10-5. Sketch of Offset for a New Airport

10.3 Secondary Analysis of Prior Data

Secondary analysis of prior data sets can lead to better understanding of an abrupt-change effect, especially the relative importance of potential mediating factors. A better understanding will guide the collection and analysis of future data towards potentially important factors and away from factors not likely to be important.

Some studies, even recent studies, have generated results that appear to contradict each other. For example, a large abrupt change effect was observed in the 14-Site Traffic Change study; following a noise exposure change respondents' annoyance changed more than expected based on the baseline curve. However, in the Bodø/Værnes study annoyance did not appear to change despite temporary increases of approximately 6 dB in noise exposure. Additional analysis may help resolve the apparent discrepancies between the studies.

In addition, secondary analysis of prior data can shed light on several options of the study design for new data. For example, "repeat" respondents would allow a more precise measurement of the abrupt-change effect, for the same number of samples, as would "non-repeat" respondents. However, dose-response relationships measured for "repeat" respondents can only be trusted if the repeat nature of this sampling method introduces no significant bias in the results. Secondary analyses of prior data may show that the opinions of "repeat" respondents are *not* biased by their prior contact with study personnel, compared to opinions of "non-repeat" respondents. In other words, even though they were previously questioned about aircraft noise, this did not affect their answers on subsequent surveys.

Such a finding from prior data would be extremely valuable to the study design for new data. It would allow new data collection to concentrate upon "repeat" respondents, without fear of bias, and include only a relatively small sample of "non-repeat" respondents, for control purposes.

10.3.1 Selection of Prior Data Sets

Data sets of interest for secondary analysis include those from aircraft studies with large noise exposure changes, and those from the most recent studies, in which it is most likely that state-of-the-art methods were used in the data collection. Only studies with enough first round data to derive a baseline dose-response curve should be considered for secondary analysis. The Burbank, Oslo, and Bodø/Værnes studies meet these general guidelines. Also, secondary analysis should be performed using the data set from the 14-Site Traffic Change study, since this is a recent study that indicated a large abrupt change effect. Secondary analysis of this data set should focus on the uncertainty limits of the results, and on the sensitivity of the results to different assumed baseline curves.

Some prior data sets can be combined for secondary analysis, others cannot. We recommend combining data sets only if they employ essentially the same aircraft dose, annoyance scale, and method for sampling respondents. Otherwise we recommend separate analyses for each data set. It should be possible to combine the Oslo and Bodø/Værnes data. The Burbank data could be combined with this data, if a relationship can be found between the 5-point annoyance scale used for the Burbank study and the 4-point annoyance scale used in the Norwegian studies.

10.3.2 Recommended Analysis

This section recommends specific investigations of prior data. These recommendations are an attempt to design the analysis before hand, without feedback from analysis results. Such attempts almost always fail in their details. During the course of the analysis, contingencies will undoubtedly arise that complicate the analysis and require departure from details of these recommendations.

Data exploration. Determine the study's dose precision, by comparing its doses with its calibration measurements. Assess whether low dose precision is likely to affect regression coefficients or their computed confidence intervals from this study.

Using the methods in Appendix B, fit single-variable regressions of response separately to each individual independent variable collected in the study. Also compute correlations among all independent variables and qualitatively estimate their general cause/effect hierarchies. Also determine potentially confounding variables (those that correlate highly with dose or ΔL), and tag these variables for special consideration later in the analysis.

Based upon these regressions, correlations, estimated cause/effect hierarchies, and potentially confounding variables, decide upon a regression hierarchy for the study's independent variables. Always place the following independent variables at the top of this hierarchy: (1) dose, (2) specific airport, (3) and ΔL, the abrupt change in dose. Note that some studies may include only one airport, or may not include an abrupt change in dose (ΔL). The analysis is stronger if it combines various studies, as described above, so that several airports are included in the combined secondary analysis. Finally, summarize the study's sampling method in statistical terms, for later use in computing regression confidence intervals.

Initial regressions. Appendix B contains details of the recommended regression method. Discussed in that appendix is the very close mathematical connection between mean annoyance and percent of people highly annoyed. This connection allows very similar regression methods and confidence interval computations for these two types of response.

Perform initial regressions of response against dose for the following situations: (1) before the abrupt change, (2) immediately after the abrupt change, and (3 etc.) all other time intervals after the abrupt change. Call these Before, After1, After2, After3, After4, and so forth. Table 10-1 shows all possible regression cases.

For these regressions, include the following independent variables: dose, specific airport, ΔL (linearly), and time lapse after the abrupt change. Obviously the "before" regression will not include ΔL and time lapse. Use the linear logistic functional form without interaction terms, as described in Appendix B.

In each of the "after" regressions, the baseline curve ($\Delta L = 0$) represents those respondents who experienced no (or very little) noise-level change. In other words, these respondents have experienced constant exposure during the time interval between "before" and "after." The regression automatically uses these respondents as the control group for respondents who did experience an abrupt change. For this reason, the baseline measure of constant exposure derives from neighborhood areas other than the ones that experienced an abrupt change.

Also using the detailed methods in Appendix B, compute standard errors and correlations of the regression coefficients, plus the confidence interval bounds on the baseline regression curve itself ($\Delta L = 0$). If the study's data were statistically clustered, then "jackknife" the regression to obtain the jackknife design effects of the study's clustered sampling plan. Then, as described in the appendix, inflate the computer program's standard errors and correlations to account for clustering.

Tests for additional complexity in functional form. Next test the need and corresponding benefit of additional complexity in the regression's functional form, compared to the linear logistic form. Statistically test the following:

- Significance of the regression coefficient for ΔL, using the linear logistic functional form. If this coefficient is statistically significant, then an abrupt-change effect has been found.

- Significance of the regression coefficient for time lapse, using the linear logistic functional form. If this coefficient is statistically significant, then the abrupt-change effect decays over time.

- The significance of a non-linear form for the ΔL term. A non-linear form will model properly if the abrupt-change effect is actually non-linear in ΔL. If it is, then use of this non-linear form is likely to improve the statistical significance of the regression coefficients for ΔL and time lapse. Retest the statistical significance of these coefficients.

- The significance of a non-linear form for the time-lapse term. A non-linear form will model properly if the decay of the abrupt-change effect is non-linear in time. If it is, then use of this functional form is likely to improve the statistical significance of the regression coefficients for ΔL and time lapse. Retest the statistical significance of these coefficients.

- Significance of a regression interaction between dose and ΔL. Interaction will model properly if the abrupt-change effect varies for different starting values of dose. If interaction is significant, then including the interaction term is likely to improve the statistical significance of the regression coefficients for ΔL and time lapse. Retest the statistical significance of these coefficients.

- Significance of a regression interaction between dose and time lapse. Interaction will model properly if the time lapse varies for different starting values of dose. If interaction is significant, then including the interaction term is likely to improve the statistical significance of the regression coefficients for ΔL and time lapse. Retest the statistical significance of these coefficients.

Table 10-1. Possible Regression Cases

Case	When surveyed				Respondents		Response		Aircraft "before"?	
	Before abrupt change	After abrupt change			Repeat	Non-repeat	Mean Annoyance	Percent Highly Annoyed	Yes	No
		1	2	3etc						
1	✓				✓		✓		✓	
2	✓				✓		✓			✓
3	✓				✓			✓	✓	
4	✓				✓			✓		✓
5	✓					✓	✓		✓	
6	✓					✓	✓			✓
7	✓					✓		✓	✓	
8	✓					✓		✓		✓
9		✓			✓		✓		✓	
10		✓			✓		✓			✓
11		✓			✓			✓	✓	
12		✓			✓			✓		✓
13		✓				✓	✓		✓	
14		✓				✓	✓			✓
15		✓				✓		✓	✓	
16		✓				✓		✓		✓
17			✓		✓		✓		✓	
18			✓		✓		✓			✓
19			✓		✓			✓	✓	
20			✓		✓			✓		✓
21			✓			✓	✓		✓	
22			✓			✓	✓			✓
23			✓			✓		✓	✓	
24			✓			✓		✓		✓

- Significance of a skew functional form in dose. If the skewness parameter is significant, then a skew fit to the data is likely to improve the statistical significance of the regression coefficients for ΔL and time lapse. Retest the statistical significance of these coefficients.

- Significance of a non-zero lower response limit. If the study included many chronically annoyed respondents, then a non-zero lower limit is likely to improve the statistical significance of the regression coefficients for ΔL and time lapse. Retest the statistical significance of these coefficients.

- Significance of a non-saturated upper response limit. If the study included many imperturbable respondents, then a non-saturated upper limit is likely to improve the statistical significance of the regression coefficients for ΔL and time lapse. Retest the statistical significance of these coefficients.

When one of these tests is successful, adopt the additional complexity and then retest the continuing need for complexity added to this point in the analysis. In other words, the need and benefit of the various complex functional forms are not independent of one another. They must be assessed in combination and the statistically best combination adopted for use.

Possible merge of "before" with each "after" data set. Temporarily merge the "before" data set separately with each "after" data set, using a dummy "before" variable of regression. Test the significance of the "before" variable in each merged regression. If not statistically significant, then permanently merge the data sets. With the merged data sets, the baseline curve for the re-regressed data will be a combination of "after" data for those respondents with $\Delta L = 0$ (or nearly zero) and all "before" respondents. If such a merge is justified, then this merged baseline is far more extensive than without the merge. This more extensive baseline is likely to improve the statistical significance of the regression coefficients for ΔL and time lapse. Retest the statistical significance of these coefficients.

If the "before" variable does turn out to be statistically significant, then the data sets cannot be merged. In this case, the "before" dose-response curve differs significantly from the baseline "after" curve (the curve for airport neighbors who experienced no abrupt increase). For "non-repeat" respondents, such a difference might be due to before/after changes in general community feelings towards the airport caused by the change itself, general items in the news, or anything else in the public mind that occurred between "before" and "after." For "repeat" respondents, such a difference might also be the "repeat" bias. Such a bias is possible because the "repeat" respondents knew about the study between "before" and "after," and were thereby pre-conditioned for the "after" survey.

Possible merge of "repeat" and "non-repeat" respondents. Temporarily merge the "repeat" data set with the "non-repeat" data set, using a dummy "repeat" variable of regression. Test the significance of the "repeat" variable. If not statistically significant, then permanently merge the data sets. Merging is beneficial because it results in fewer dose-response curves, each with greater precision. Note that confidence intervals are tighter for the "repeat" respondents.

If the coefficient of the "repeat" variable does turn out to be statistically significant, then assess and discuss the meaning of this difference. Significance here indicates a bias in the "repeat" respondents, perhaps caused by their prior association with the study.

Attempt to increase statistical significance of ΔL and time lapse, by including mediating factors. Test the statistical significance of potential mediating factors by systematically adding other independent variables into the regression. Add these variables in the regression hierarchy decided above. For each variable, test its statistical significance and whether or not it statistically confounds the coefficients of variables already in the regression (and therefore considered more important in the variable hierarchy).

When an independent variable is statistically significant to the regression, then it is a good candidate for inclusion in the dose-response equation. Its inclusion will generally reduce the residual scatter of the regression and generally cause coefficients of ΔL and time lapse to be known to a greater precision. This additional precision for the coefficients of ΔL and time lapse comes at a price, however. Each additional variable in the dose-response equation makes later use of the equation more complicated, because the value of that variable must then be evaluated. Obviously, some variables are more difficult to determine for new airports than are others. In this regard, one would attempt to strike a meaningful balance between (1) the increased precision brought by additional variables and (2) the increased difficulty of using a dose-response equation with additional variables.

Possible merge of all "after" data. If the time-lapse coefficient of regression is not significant, then merge all "after" data sets. Then recompute the coefficient on ΔL and reassess its statistical significance.

10.4 Collection of New Data

Further data collection designed to measure the abrupt change effect and its decay would help resolve whether people respond differently to abrupt noise exposure changes than to gradual changes or to changes predicted using standard dose-response curves. Further data collection would help resolve whether or not an abrupt change effect decays over time, and if so, how quickly.

Any additional research concerning these topics should start with efforts to locate airports in the U.S. where abrupt changes in noise exposure are expected. These efforts should be coordinated with NASA, the FAA, and FAA regional offices. At airports identified through these efforts, noise modeling should be used to estimate the size of the noise exposure changes, and the potential size of the study population. A survey instrument applicable to change in noise exposure studies at U.S. airports should be designed and submitted for approval by the Office of Management and Budget (OMB). The survey instrument should be designed such that it is applicable to all of the airports at which data collection may occur.

10.4.1 Study Design

Future research should involve multiple, longitudinal rounds of interviews at one or more U.S. airports experiencing a change in noise exposure. The first round of interviews should be conducted shortly before the change in noise exposure. The second round of interviews should be conducted within two weeks following the change in exposure. At least one or two additional rounds of interviews should be conducted to measure whether there is a decay in the abrupt change effect. Noise measurements should be conducted prior to and simultaneously with the interviews.

At least a portion of the respondents in the study should be repeat respondents (interviewed each round) and a portion should be non-repeat respondents. The relative proportions of repeat and non-repeat respondents should be determined based on the results of the secondary analysis, and on the size of the study area population.

The following considerations are important in the study design:

- If possible, airports should be chosen for which a very large abrupt change in dose is expected: at least 5 dB, preferably 10 dB or more. It is preferable to measure both increases and decreases in noise exposure at one airport. The study population should include residents with noise exposure increases, residents with decreases, and residents with little or no change in noise exposure.

- The analysis is simplified for airports where the target noise is pre-existing (exists and predominates in the "before" situation). Dose-response curves developed with pre-existing target noise would directly predict the effects of noise changes at existing airports. Without pre-existing target noise, dose-response curves would not predict this directly. Instead, they would predict responses for newly introduced target noise, which may also be of interest.

- For most efficient use of resources, telephone interviews should be used rather than face-to face interviews. A reverse telephone directory can be used to help define the study area population.

- To whatever extent feasible, the sampling method should be purely random, not clustered. A random sample allows for a straightforward assessment of dose-response confidence intervals. If clustered sampling is used then the jackknife or similar procedure must be used to correctly calculate the uncertainty limits of the dose-response curves. It may be necessary to sample a larger group in the first round of interviews, or in later rounds to over-sample people with very large changes and no changes. It is expected that the abrupt change effect will be most noticeable in residents with the largest changes in noise exposure, and not noticeable in residents with no change, thus providing the best test for an effect.

- One round of interviews should be conducted a year after the change in noise exposure to measure the decay of the abrupt change effect, independent of potential seasonal influences.

10.4.2 Acoustic Dose Determination

The acoustic dose for each respondent should be determined based on a combination of noise level projections and acoustic measurements. The goal should be to calculate, as accurately as possible, the outdoor aircraft DNL for each respondent in the week prior to each round of interviews. Since it is not feasible or measure the actual noise exposure for each resident, noise projections should be used to extrapolate to areas not measured.

Noise level measurements should be conducted continuously throughout the week prior to each round of interviews using state-of-the-art methods. The measurement results should be compared to noise projections made using the Integrated Noise Model (INM). In using INM, it is preferable that actual flight track data, such as that provided by an ARTS system, be used as input. After resolving any major discrepancies between the measurements and projections, projections should be performed for each respondent.

10.4.3 Mediating Factors

The mediating variables discussed in Section 3 and Section 6 should be tested for their influence of the dose-response relationships. It is expected that the specific study area or areas will be the single most important mediating variable. A number of other mediating variables may influence the results. Some can be measured, such as day-to-day variability in DNL and respondent location relative to flight tracks. Others should be included in the survey instrument, such as respondents' concern regarding air crashes, perceived concern of airport officials, and demographics.

With regard to attitudes and expectations, the concept of "critical tendencies," as discussed by Weinstein, should be explored to the extent feasible. Particularly in an area in which aircraft are not the dominant noise sources, it may be possible to use responses in the first round of interviews to determine respondents' critical tendencies. Where aircraft noise already dominates the noise environment, it may be difficult to establish causality in the relationship between noise annoyance and other respondent attitudes and expectations.

In addition, happenstance variables, such as specific day of the interview and specific interviewer, should be tabulated for later testing in the analysis. It is not expected that these variables would influence the results, but testing for their influence strengthens the results of the study.

10.4.4 Response Determination

The survey instrument should be designed in consultation with NASA and the FAA. If possible, the same survey instrument should be used for each airport or study area. Prior surveys provide a wealth of examples of exactly which questions to include in future work, and should be used as much as possible to guide future work. The survey should be kept as short as possible, but should contain the following components:

- A question regarding annoyance due to aircraft noise. The question should specify the time period for evaluation (most likely one week), that the respondent evaluate noise heard "while at home", and should ask the respondent to rate the noise on the 5-point category scale typically used in U.S. airport studies.

- Questions regarding annoyance due to other environmental noise, especially for areas where other sources besides aircraft may dominate the noise environment.

- Questions regarding general attitudes concerning the respondent's neighborhood, and attitudes directed towards airplanes (fear of air crashes) and airport officials.

- Demographic information. Some information may be collected without questioning the respondent (general neighborhood characteristics, address); questions should be included to collect other demographic information, particularly concerning length of residence.

10.5 Analysis of New Data

Following secondary analysis of prior data, and collection of new data, the new data should be analyzed using the methods described in Section 10.3. It may be possible to combine prior data with the new data. The analysis methods should be modified to account for experience with the analysis of prior data, plus specific details of the new data collected.

In general, the analysis of new data will be more complete than the secondary analysis, because the data are more complete. The new data set will include a full range of "before" and several successive "after" phases, which prior studies may lack. Also, it will include zero-change respondents in the "after" study, as baseline, which allows an independent measure of "repeat"-respondent bias.

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GLOSSARY

This section provides a brief description of the terminology used in this report. Both words and expressions are defined here in the context in which they are used in the report.

Data Set - The tabular collection of dose, response and demographic information for each respondent in a single survey.

Questionnaire - The actual form used by the interviewer to administer questions to respondents. The form includes not only the questions and the order in which they are to be read, but also instructions for conditionally selecting specific blocks of questions based on respondents' answer to a previous question.

Neighborhood - A limited geographic area from which a sample population is drawn to administer a survey, and over which a small variation in dose is expected so that the respondents may be characterized as having similar or identical doses.

Survey - A single, coordinated data collection effort, to obtain information at either (1) a number of different locations at a single point in time, or (2) the same locations at repeated points in time.

Survey Instrument - Instructions to interviewers, and the questionnaire itself.

APPENDIX A. SYNOPSES OF INDIVIDUAL STUDIES

This appendix contains brief descriptions of the studies of the change in noise exposure studies reviewed in this report. They are organized by noise source, with aircraft in Section A.1, roadway in A.2, railway in A.3 and other sources in Section A.4.

A.1 Airport Investigations

A.1.1 Heathrow

Directorate of Operational Research and Analysis: 1971. Aircraft Noise in the Neighborhood of London Heathrow Airport, 1967. DORA Report no. 7105. Dept. of Trade and Industry, London. [UKD-024]

Knowler, A.E.: 1971. The Second Noise and Social Survey Around Heathrow, London Airport. 7th International Congress on Acoustics, Budapest, Vol. 2, August 18-26, 1971, pp. 525-528. [UKD-024]

MIL Research: 1971. Second Survey of Aircraft Noise Annoyance Around London (Heathrow) Airport. Her Majesty's Stationery Office, London. [UKD-024]

Description. This study concerns annoyance due to noise from Heathrow Airport. A survey had been conducted of people living near the airport in 1961. A second survey was commissioned in 1967. Over this time the number of aircraft operations at Heathrow increased from approximately 377 to 545 per day.

In the first survey approximately 2,000 people within a radius of 10 miles from the airport were interviewed over a 3-month period. In 1967 approximately 5,000 people were interviewed from an area 20 by 30 miles wide were interviewed over a 3-month period, although a subset of people within a radius of 10 miles from the airport was identified for the purpose of comparing with the previous study. From response to a detailed questionnaire, two daytime and two nighttime annoyance scales were derived. These were based on whether or not aircraft caused annoyance, and the extent to which aircraft noise caused activity interference. An effort was made to demonstrate that the annoyance scales were approximately linear. In the sampling an effort was made to get a large range of Noise and Number Index (NNI) values. Areas with large numbers of aircraft but relatively low peak noise levels (and vice versa) were over-sampled, and this over-sampling was factored into the results.

Measurements were conducted of peak noise level, number of aircraft, and day/night distribution of aircraft operations. In 1961 approximately 8,500 aircraft events were measured at 85 positions. In 1967 approximately 28,000 aircraft events were measured at 126 positions (90 for departures, 36 for arrivals). The measurements were used to calculate NNI for clusters of residences. NNI contours were used to extrapolate to areas where no measurements were performed.

Results. The investigators concluded that annoyance increased very slightly from 1961 to 1967. Annoyance was measured on a composite scale, but was highly correlated with the four-point aircraft annoyance question. Although annoyance changed little between the two years, airport operations increased by 45%. For the sample within 10 miles of the airport, the mean peak level of aircraft stayed about the same, and the mean number of aircraft per day increased from 22 to 48, or 118%. Thus, despite a noise exposure increase of approximately 3 dB, there was no significant increase in annoyance.

The investigators examined the affects of mediating variables. Between 1961 and 1967 there was a considerable reduction in the number of people afraid of air disasters, and a considerable increase in the number of people who had been on an airplane.

A.1.2 Los Angeles

Fidell, S.; and Jones, G.: 1975. Effects of Cessation of Late-Night Flights on an Airport Community. J. Sound Vibration, Vol. 42, no. 4, pp. 441-427. [USA-082]

Description. This study concerns changes in annoyance caused by changes in noise exposure near Los Angeles International Airport. In April 1973 approach patterns were altered such that between the hours of 23:00 and 6:00, aircraft approached the airport over Santa Monica Bay west of the airport, rather than over the populated areas east of the airport. During the daytime hours approach and departure patterns were unchanged. As a result of the change, the number of approaches made from east of the airport dropped by approximately 50 per day from an average of approximately 687.

Three rounds of interviews were conducted: shortly before the change, shortly after the change, and a month after the change. Areas of high noise exposure (DNL of 80 to 85) and moderate exposure (DNL 60 to 65) were sampled. 208 people in the high noise area and 258 people in the moderate noise area were interviewed in the first round, and then interviewed again in the second and third rounds. However, by the third round the number of respondents in the panel sample had dropped to 111 in the high noise area and 107 in the moderate noise area. Also, separate control samples obtained for the first and third rounds of interviews; respondents in the control samples were interviewed only once. For the first round the control group consisted of 120 people in the high noise area and 120 in the moderate noise area. For the third round, the control group consisted of 117 in the high noise area, and 117 in the moderate noise area. The survey consisted of 37 questions, including 22 questions concerning noise, 3 concerning expectations, and 11 concerning demographics. At the end of the interview the respondent was asked whether or not he or she had noticed an increase or decrease in the number of aircraft flights around their house in the past month.

Noise measurements were conducted before and after the change in noise exposure. Also the number of aircraft operations was recorded each day before and after the change. The noise measurements, given in terms of hourly Leq's for a 24-hour period at one representative position, confirmed that nighttime noise levels dropped significantly, from approximately 75 dB(A) in the high noise area before the change to 50 dB(A) afterwards. DNL dropped less than 3 dB, since the change in the total number of operations was relatively small.

Results. Although there was a significant decrease in nighttime noise exposure, and a modest decrease in DNL, there was no corresponding, significant drop in annoyance. In fact, annoyance increased slightly (but not significantly) between the first and second interviews. In exploring the reasons for this result, the investigators highlight the possibilities that residents' may not have had enough time to experience a change in sleep patterns between the interviews, and that the change in noise exposure may have been too small to cause a drop in annoyance, but argue against any inadequacy in the measurements.

A.1.3 Roissy

Francois, Jacques: 1979a. Les Répercussions Du Bruit Des Avions Sur L'Equilibre Des Riverains Des Aéroports: Etude Longitudinal Autour De Roissy, 3ème Phase (Effects of Aircraft Noise on the Equilibrium of Airport Residents: Longitudinal Study Around Roissy, Phase 3). IFOP/ETMAR , Paris. Translation available as: Effect of Aircraft Noise on the Equilibrium of Airport Residents: Longitudinal Study Around Roissy - Phase III. NASA TM-75906, 1981. [FRA-150]

Description. This study concerns annoyance due to aircraft noise of residences around Roissy, France near Charles de Gaulle Airport. Charles de Gaulle Airport opened in 1974. Residents were interviewed shortly before it opened, a year after it opened, and 3-1/2 years after it opened. At the time of the second interview, another interview was conducted of residents near Orly Airport, where airport traffic had slowly increased over a period of years.

The first round of interviews included 690 residents. The second round included 484 residents, all who had been questioned in the first round. The third round included 943 residents. Of these, only 218 had been questioned before, but all had been in the area since before the airport opened. At Orly Airport 997 residents were interviewed. The interview included a number of questions about the respondent's expectations, opinions, and health, as well as questions related to aircraft noise. There were a number of annoyance questions. The most analysis appears to have been based on a question of how frequently aircraft noise annoyed the respondent: "very often," "fairly often," "sometimes," and "never." Other questions asked about nighttime annoyance and the degree of annoyance at different times of day.

Noise measurements were not used for the study. Instead, each respondent was assigned a value of the "noise index" determined using contours prepared by the Paris Airport Authority.

Results. In terms of general annoyance due to aircraft, the investigators found little difference in the response as a function of noise index at Orly in 1975, Roissy in 1975, and Roissy in 1977. This conclusion is based on a graph of the percentage of respondents reporting that aircraft noise annoys them very often as a function of noise index. Data from all three of the studies falls along a line.

The exception to this result was in nighttime annoyance. The percentage of people around Roissy reporting nighttime annoyance dropped between 1975 and 1977, possibly because of habituation.

A.1.4 Burbank

Fidell, S.; Horonjeff, R.; Teffeteller, S.; and Pearsons, K.S.: 1981. Community Sensitivity to Changes in Aircraft Noise Exposure. NASA CR-3490. National Aeronautics and Space Administration, Washington, D.C. [USA-203]

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Griffiths, I.D.; and Raw, G.J.: 1985a. Author's Reply. J. Sound Vibration, Vol. 102, pp. 585-587. [USA-203]

Fidell, S.; and Pearsons, K.S.: 1985b. Comments on Reply to "The Effect of Change in Aircraft Noise Exposure". J. Sound Vibration, Vol. 103, pp. 139-140. [USA-203]

Griffiths, I.D.; and Raw, G.J.: 1985b. Author's Reply. J. Sound Vibration, Vol. 103, pp. 140-141. [USA-203]

Description. This study concerns changes in annoyance caused by changes in noise exposure near Burbank-Glendale-Pasadena Airport. This airport is primarily a general aviation airport with some jet operations In September 1979 the main runway underwent repairs. When repairs began all jet operations and many of the general aviation operations were diverted to a cross runway. Later the main runway was closed to all air traffic until December 1979. Several months later repairs began on the cross runway and were completed in October 1980.

Five rounds of interviews were conducted - once before repairs began, three times during repairs, and once 3 months after all repairs were complete. Interviews were conducted in 4 neighborhoods. Neighborhood A was subjected to a noise exposure decrease from a DNL of 77 dB(A) to a DNL of 58-60 dB(A). Neighborhood B was subjected to an increase from 59 dB(A) to 68-70 dB(A). The noise exposure at Neighborhood C decreased from 65 dB(A) to 56-58 dB(A), and the noise exposure at Neighborhood D increase slightly from 61 dB(A) to 63-66 dB(A). The neighborhoods were selected based on NOISEMAP contours, such that all of the homes in the neighborhood had approximately the same noise exposure (within 3 dB). The survey asked respondents to rate their long-term (past year) and short-term (past week) annoyance on a five point scale with the categories: "Not at All," "Slightly," "Moderately," Very," and "Extremely."

Noise measurements were conducted at one house in each neighborhood the week before each round of interviews was conducted. The noise monitor measured A-weighted sound levels and event statistics. The measurements were reported in terms of DNL. Based on the NOISEMAP contours developed for the airport, the authors believed that the measurements were representative of the entire neighborhood, with a range of approximately 3 dB for the neighborhood.

Results. Annoyance clearly changed as a result of changes in noise exposure in each of the neighborhoods. All analysis was based on DNL and the percentage of people highly annoyed. High annoyance included the response categories of "Very" and "Extremely." The investigators demonstrated that short-term annoyance closely followed changes in noise exposure, while long-term annoyance changed more slowly, demonstrating that people were able to judge short-term versus. long-term and integrated noise levels over time to determine their long-term annoyance. It was difficult to discern any adaptation to the temporarily higher or lower noise levels, that would be expected to occur if people initially overreacted to a change.

All of the data points for annoyance versus noise exposure were well above the Schultz curve, and the investigators devoted a considerable amount of the discussion to exploring these differences. The political atmosphere between the airport and community was highly-charged, and this may have been a factor. One factor in the results was that the change was temporary and the community had been informed beforehand that a change would occur. Differences from the Schultz curve could have had something to do with the type of airport, as the airport had a large number of general aviation operations, or the audibility of aircraft in the neighborhoods compared to other neighborhoods survey in studies that are included in the Schultz curve.

Raw and Griffiths later explored how the change in noise exposure may or may not have caused larger changes in annoyance than would have been expected based on a curve derived from the steady state (before any change) data. Based on the DNL measurements and mean annoyance scores they concluded that the change in noise exposure did cause a larger change than would be expected based on a baseline curve. Fidell and Pearsons disputed Raw and Griffiths' work, primarily because Fidell and Pearsons disagreed with the use of mean annoyance rather than % highly annoyed. Supplementary analysis has indicated that Raw and Griffith's methodology, applied to % highly annoyed rather than mean annoyance, yields comparable results.

A.1.5 Orange County

U.S. Department of Transportation Federal Aviation Administration: 1981. Evaluation of Three Noise Abatement Departure Procedures at John Wayne Airport. Washington, D. C. [USA-204]

Fidell, S.; Mills, J.; Teffeteller, S.; and Pearsons, K.: 1982. Community Response to Three Noise Abatement Departure Procedures at John Wayne Airport. BBN Rep. 4743. [NASA contract NASI-16521] [USA-204]

Fidell, S.; Horonjeff, R.; Mills John; Baldwin, Edward; Teffeteller, S.; and Pearsons, K.S.: 1985. Aircraft Noise Annoyance at Three Joint Air Carrier and General Aviation Airports. J. Acoust. Soc. Am., Vol. 77, no. 3, pp. 1054-1068. [USA-203 USA-204 USA-301]

Description. This study concerns changes in annoyance caused by changes in noise exposure near John Wayne Airport. In September and October of 1981 jet departure flight profiles were changed to cause reductions in noise exposure. Three alternative profiles were used, each for approximately 2 weeks. As a result of the changes in profiles, mean aircraft Lmax levels near the airport dropped significantly. However, DNL in residential areas changed very little, partially due to the large number of propeller aircraft operations that was unchanged throughout the study.

Four rounds of interviews were conducted: once before any changes in flight profiles, and three additional times after a change had been in effect for two weeks. Interviews were conducted of residents in three noise exposure zones near the airport. The zones were chosen such that residents within a given zone had comparable aircraft noise exposure (although exposure varied by as much as 12 dB within a zone). Half of the telephone subscribers in Zone 1 (out of 550), One-third of the telephone subscribers in Zone 2 (out of 1200), and one-tenth of the telephone subscribers in Zone 3 (out of 4000) were contacted for each round of interviews. Over 3,100 interviews were conducted. The interview consisted of 5 questions: one asking the respondent how long they had lived at their current address, one question on annoyance due to traffic noise annoyance, and 3 questions concerning annoyance due to aircraft. For the annoyance question the respondents were first asked if they were annoyed at all; if they were they were asked to rate their annoyance on a 5-point scale ranging from "Not at All" to "Extremely."

Noise measurements were conducted continuously at six locations using the airport noise monitoring system. The measurement results and NOISEMAP contours were used to calculate the two-week energy average DNL in each zone for the two weeks preceding each round of interviews. Before the changes DNL was 67.1 in Zone 1, 61.8 in Zone 2, and 59.0 in Zone 3. The greatest reduction in DNL was 1.8 dB in Zone 1 for the third round of interviews. Typically DNL did not change by more than 1 dB between the interviews, and in some cases increased relative to the DNL measured before the changes.

Results. The investigators found little change in noise exposure and little change in annoyance. The reduction in noise exposure was at most 1.8 dB, and in certain rounds there were increases rather than decreases in DNL. A linear relationship was derived between percent highly annoyed and DNL. This relationship had good correlation and agreed well with the Burbank data, as with data from other studies. However, the relationship predicted considerably greater levels of annoyance than the Schultz curve.

A.1.6 Oslo

Gjestland, T.; Liasjø, Kåre H.; Granøien, I.; and Fields, J.M.: 1990. Response to Noise Around Oslo Airport Fornebu. DELAB Report No. STF40 A90189. [NOR-311]

Gjestland, Truls; Granøien, Idar L.N.; Liasjø, Kåre H.; and Bugge, Jens-Jørgen: 1994. Response to Noise around Værnes and Bodø Airports (Draft). DELAB Report No. STF40 A94095. [NOR-311 NOR-328]

Description. This study concerns community response to increased noise from a short term operations change at Oslo Airport Fornebu in Norway. From May to September 1989 another Oslo airport, Gardermoen, was closed for refurbishing, and most of its flights were shifted to Fornebu, increasing air traffic at Fornebu by approximately 7.4%. The change caused increases in DNL that were generally less than 3 dB, but in some cases as much as 10 dB. The purposes of the study were to assess the impact of aircraft noise on the community under normal operating conditions, to evaluate the impact of a sudden increase in the amount of air traffic, and to identify any air traffic or other characteristics which affect community reactions.

Interviews were conducted in April shortly before the change and from the end of August to the beginning of September, shortly before the airport reverted to its normal operations. 1554 people were interviewed in the first round and 1800 were interviewed in the second round. The respondents were randomly selected from each of 15 different areas. The noise exposure was nearly equal within each of the areas. During the interviews, respondents who reported hearing aircraft were asked if they found the aircraft very, quite, a little or not annoying. There were separate questions for annoyance inside the house, outside the house, on weekends and in the evening. No particular exposure period was specified in the interview.

Noise measurements were conducted at 22 locations and compared with projections made using INM and radar tracks. The projected levels were used in the data analysis. Noise levels are reported in terms of EFN, which is comparable to DNL, but with different nighttime adjustments. The investigators recommend subtracting 1 dB from EFN to convert to DNL. Adjustments were made for individual respondents' noise exposure using the contours.

Results. The investigators derived dose-response relationships relating EFN to annoyance. Mean annoyance and percentage very annoyed (since there were only 4 categories in the annoyance question "very annoyed" is equivalent to the generally accepted definition of "highly annoyed") were examined using linear regression, logistic regression, and power transformation. Also, separate curves were derived for the two rounds of interviews to determine if respondents had become more sensitized to noise as a result of the change. The investigators found the increased sensitivity was equivalent to no more than 1.8 dB, not significantly different from 0.

A.1.7 Atlanta

Fidell, Sanford; and Silvati, Laura: 1989. An Assessment of the Effect of Residential Acoustic Insulation on Prevalence of Noise Induced Annoyance in an Airport Community. BBN Rep. 7132. [USA-349]

Fidell, Sanford; and Silvati, Laura: 1991. An Assessment of the Effect of Residential Acoustic Insulation on Prevalence of Annoyance in an Airport Community. J. Acoust. Soc. Am., Vol. 89, pp. 244-247. [USA-349]

Description. This study concerns changes in annoyance caused by an acoustical insulation program at Hartsfield International Airport in Atlanta. Approximately 2500 residences near the airport had been treated to increase their acoustic transmission loss by approximately 5 dB. The study focused on approximately 1200 residences that had been treated for at least 8 months. The purpose of the study was determine whether acoustic insulation resulted in a decrease in annoyance.

Residences near the airport were placed in one of four categories based on aircraft DNL determined from noise contours: 65 to 67.5 dB(A), 67.5 to 70 dB(A), 70 to 72.5 dB(A), and 72.5 to 75 dB(A). An exhaustive telephone survey was made of these areas. Of a total of 1188 insulated homes, there were 589 completed interviews. Of 1071 non-insulated homes, there were 352 completed interviews. The interview consisted of a series of questions about the respondent's attitudes and expectations concerning the neighborhood, annoyance due to traffic noise, and annoyance due to aircraft noise. For the noise annoyance questions, the interviewer first asked if the respondent was annoyed, and if he or she was, the interviewer asked the respondent to rate their degree of annoyance on a 5-point scale that ranged from "Not at All" to "Extremely."

No noise measurements were conducted in connection with this project. Residences were classified into the categories listed above based on contours provided by the airport.

Results. The investigators concluded that acoustic insulation does little to reduce the prevalence of annoyance in airport neighborhoods. Of the four categories, the sample was too small in one to make any conclusions, the percent highly annoyed was 2% lower for treated homes in one, 17% lower in another, and 5% higher in another. Although the 17% difference was found to be significant, the investigators maintained that it was not a large difference, and reiterated the lack of conclusive results for the other three categories. The percentage of people annoyed (to any degree) due to traffic noise was 30% for the treated homes and 15% for the untreated home. This result was stated but not discussed.

The clear and thorough documentation of the results makes possible further analysis of the survey data. Based on the populations of each of the three categories (leaving out the 65 to 67.5 dB(A) category for lack of data) and the percentages for each degree of annoyance sampled in each category, estimates of the annoyance of the total population have been derived. The estimates indicate that approximately 50% of the untreated population is highly annoyed, compared to 43% of the treated population. The mean annoyance (on a scale of 0 to 4) of the untreated population is 2.22, compared to 2.12 for the treated population. These figures (not accounting for the uncertainty of the results) indicate that acoustic insulation reduces the percentage highly annoyed by approximately 7%.

A.1.8 Bodø/Værnes

Gjestland, Truls; Granøien, Idar L.N.; Liasjø, Kåre H.; and Bugge, Jens-Jørgen: 1993. Community Response to Noise From a Short Term Military Aircraft Exercise. In Noise and Man '93: Noise as a Public Health Problem (Proceedings of the Sixth International Congress), Volume 2, pp. 589-592. INRETS, Arcueil, France. [NOR-328]

Bugge, Jens-Jørgen: 1994. Community Response to Noise from Short Term Military Aircraft Exercises at Airports Serving Both Civil and Military Traffic. Proceedings of Inter-Noise 94, pp. 243-246. [NOR-328]

Gjestland, Truls T.; Granøien, Idar L.N.; Liasjø, Kåre H.; and Bugge, Jens-Jørgen: 1994. Response to Noise around Værnes and Bodø Airports (Draft). DELAB Report No. STF40 A94095. [NOR-328]

Gjestland, Truls T.; Liasjø, Kåre H.; and Granøien, Idar L.N.: 1994. Response to Noise around Værnes and Bodø Airports. Report No. STF40 A94095. STINEF DELAB, Trondheim, Norway. [NOR-328]

Gjestland, Truls; Granøien, Idar L.N.; Liasjø, Kåre H.: 1995. Community Response to Noise From a Short Term Military Aircraft Exercise. Proceedings of the 15th International Congress on Acoustics. vol. 2, pp. 109-112. [NOR-328]

Gjestland, Truls T.; Liasjø, Kåre H.; and Granøien, Idar L.N.: 1995. Community Response to Noise From a Short-Term Military Aircraft Exercise. J. Sound Vib., vol. 182, no. 2, pp. 221-228. [NOR-328]

Description. This study concerns community response to increased noise from short-term military aircraft exercises near Bodø Airport and Trondheim Airport Værnes in Norway. Military aircraft exercises occur at these airports periodically for periods of 2 to 3 weeks. The military operations cause a temporary increase in DNL of approximately 6 dB at Bodø and 3 dB at Værnes. The purpose of the study was to measure how annoyance changed during the military exercises, and whether or not any increase in annoyance persisted after the exercises were completed. The study took place between August 1990 and February 1993.

There were 6 rounds of interviews at Bodø and 4 rounds of interviews at Værnes. At Bodø exercises were held in March and September of 1992. Interviews were conducted in February before the first exercises, in March during the first exercises, in April after the first exercises, in August before the second exercises, and in October 1992 and February 1993 after all of the exercises. There were approximately 700 respondents per round of interviews. Approximately 500 were randomly selected and interviewed only once, and 200 were from a panel of respondents questioned each round. During the interviews, respondents who reported hearing aircraft were asked if they found the aircraft very, quite, a little or not annoying. The respondents gave the degree of annoyance for the past day, past month, past 6 months, and past year.

At Værnes exercises were held in September of 1990. Interviews were conducted in August before the exercises, in September during the exercises, and in October 1990 and August 1991 after the exercises. There were at least 250 respondents per round of interviews. Approximately 100 were in a panel that was interviewed each round. The rest were randomly selected. It became necessary to interview some of the randomly selected respondents more than once due to the limited population in the study area. The same interview was used at both airports

Noise measurements were conducted and compared with projections made using INM and radar tracks. The projected levels were used in the data analysis. Noise levels are reported in terms of EFN, which is comparable to DNL, but with different nighttime adjustments. The investigators recommend subtracting 1 dB from EFN to convert to DNL.

Results. The investigators reported that noise exposure increased an average of 6 dB at Bodø and 3 dB at Værnes. The results were reported primarily using bar graphs grouped by 5-dB contour intervals. The results indicated that annoyance did not increase significantly during the exercises. A logistic curve was fit to the data from all of the rounds at both of the airports. This curve was lower than the curve derived for the Oslo data, but was very similar to the Schultz curve.

A.2 Highway Investigations

A.2.1 Huddinge

Jonsson, E.; and Sörensen, S.: 1973. Adaptation to Community Noise - A Case Study. (Letter) J. Sound Vibration, Vol. 26, pp. 571-575. [SWE-026]

Jonsson, E.; Sörensen, Stefan.; Arvidsson, Ola; and Berglund, Kenneth: 1975. Reliability of Forecasts of Annoyance Reactions. Arch. Environ. Health, Vol. 30, February 1975, pp. 104-106. [SWE-011 SWE-015 SWE-026]

Description. This study concerns adaptation to an increase in noise exposure caused by the opening of a highway in Huddinge, Sweden. Interviews were conducted in 1967 six months after the highway opened, and again a year later in 1968. The purpose of the study was to determine the extent to which the population adapted to the increase in noise exposure.

Interviews were conducted based on a random sample of people living near the highway. 84 people were interviewed in 1967, and 60 of the 84 were interviewed a year later. The survey included general questions about the respondent's background, questions about housing conditions, and specific questions about traffic noise and the respondent's attitude to noise.

Noise measurements were conducted to determine mean energy noise levels of car and trucks. The measurements were conducted at three positions for each of the two sets of interviews. At each position approximately 80 events were measured. Mean energy levels were generally consistent between 1967 and 1968. However, there were no Leq measurements or traffic counts reported.

Results. The interview results were reported in a number of ways for the two sets of interviews: percent of respondents undisturbed, disturbed to any degree, and highly disturbed; percent undisturbed, disturbed at most twice a week, and disturbed daily; percent awakened; percent with medical symptoms; and percent with activity disturbance. It is not clear from the references what scale was used in the disturbance questions.

Overall, the percent of respondents reporting some type of disturbance or interference rose between 1967 and 1968. In 1967 48% were disturbed to some degree and 17% were highly disturbed; in 1968 60% were disturbed to some degree and 20% were highly disturbed. Based on these results the authors concluded that there had not been a habituation (adaptation) to the increased noise from the highway.

The investigators caution that the study was limited by the fact that there could have been habituation to noise before the first interview, by the particular noise conditions of the highway, and by the panel method employed for the study.

A.2.2 Heston

Scholes, W.E.; Mackie, A.M.; Vulkan, G.H.; and Harland, D.G.: 1974. Performance of a Motorway Noise Barrier at Heston. Applied Acoustics, Vol. 7, pp. 1-13. [UKD-050]

Scholes, W.E.: 1977. The Physical and Subjective Evaluation of Roadside Barriers. Proceedings of Inter-Noise 77, pp. A144-A153. [UKD-050]

Description. This study concerns response to a reduction of traffic noise from a noise barrier in Heston, Great Britain. The barrier was built in late 1970 along the M4, a six-lane road carrying approximately 73,000 vehicles per 18-hour day. Approximately 30% of the vehicles on the M4 were trucks, and the typical vehicle speed was 85 km/hr. In this area the M4 is elevated. Before the barrier was built the first floor of nearby residences were slightly shielded from the road by the edge of the roadway and by a wooden fence. Surveys were conducted before and after the barrier was built at houses that were protected by the barrier, and at houses across the road from the barrier.

The first round of interviews was conducted in September 1970. The second round was conducted approximately one year later. Approximately half the population in the experimental group (behind the barrier) and half the population in the control group (on the other side of the road) were interviewed before the barrier was built. The entire population of each group was interviewed in the second round after the barrier was built. In the experimental group there were 189 respondents, 63 on Winchester Avenue in the first row of houses approximately 20 m from the M4. In the control group there were 124 respondents, 79 in the first row on Durham Avenue. The interview consisted of a series of questions about the area, and of questions pertaining specifically to noise from the M4. Respondents rated the amount of noise from the M4 on a 9-point scale. After the barrier was constructed, respondents were asked about the appearance and effectiveness of the barrier.

Noise measurements were conducted at various heights on both sides of the M4 before the wooden fence was removed, after the wooden fence was removed, and after the noise barrier was constructed. Different metrics were measured for varying durations, but the measurements were reported in terms of L10 from 1 to 4 p.m. The measurements showed that the wooden fence reduced noise levels by 1 to 5 dB, and the noise barrier, relative to the fence, reduced noise levels approximately 4 dB on the first floor of the first row. With the fence the short-term L10 was 70 to 77 dB(A).

Results. The investigators concluded that with the noise barrier the median dissatisfaction score dropped slightly. On Winchester Avenue, where the noise level dropped approximately 4 dB, the median dissatisfaction dropped from 6.8 to 5.5. On Eton Avenue noise levels dropped approximately 1 dB and median dissatisfaction dropped from 5.0 to 4.3. On Durham Avenue there was no drop in noise levels, but median dissatisfaction nonetheless dropped from 6.5 to 6.2. The social survey and noise measurements were performed separately, and there was no attempt to estimate pre-barrier noise levels or noise reductions for individuals.

A.2.3 Minneapolis

Lambert, R.F.; and Bouchard, T.J.: 1974. Experimental Evaluation of a Freeway Noise Barrier: I-35W at Minnehaha Creek, Minneapolis, Minnesota. Project 00-132. Office of Research and Development, Minnesota Dept. of Transportation, St. Paul, Minnesota. [USA-069]

Lambert, R.F.: 1978. Experimental Evaluation of a Freeway Noise Barrier. Noise Control Engineering, Vol. 11, no. 2, pp. 86-94. [USA-069]

Description. This study concerns response to a reduction of traffic noise from noise barriers in Minneapolis, Minnesota. The noise barriers were constructed in 1973 along a section of I-35W that had a total traffic volume of over 100,000 vehicles per day. The barriers were constructed parallel to one another in the section of the road between Minnehaha Creek and Diamond Lake Road. The roadway was elevated near the creek at one end of the area, and depressed for a cross bridge at the other end. Surveys and measurements were conducted in the summer of 1972 before the barriers were built, and again in the summer of 1973 approximately 7 months after the barriers were completed.

The first round of interviews was conducted between June and August of 1972. The interviewers attempted to interview 15 residents per row of houses east of the freeway, and all of the residents west of the freeway. There were 6 rows of houses east of the freeway and 3 west of the freeway. A total of 151 residents out of a population of 238 were interviewed in 1972. The second round of interviews was conducted between July and August of 1973. Interviews were conducted for the same residents that were interviewed in the first round. However, since some people moved away or refused further interviews, the second round consisted of 121 interviews. The survey consisted of a series of questions about the freeway, and asked respondents to rate their annoyance due to noise (overall and for different times of day) and other factors on a seven-point scale that ranged from "unobjectionable" to "absolutely intolerable." In the 1973 survey, respondents were asked additional questions about the barrier, and whether the noise had gotten better or worse.

Noise measurements were conducted at 12 positions (three distances from the freeway at each of 2 sites on either side of the freeway) before and after construction of the noise barriers. At each position 1-hour measurements were conducted at each position for 4 different times of the day. The noise metrics calculated included Leq, L10, L50, and L90. Before construction of the barrier, at the first row of homes, the daytime L_{eq} was typically greater than 65 dB(A), and the nighttime Leq was typical greater than 57 dB(A). The noise barrier reduced noise levels approximately 10 dB at the first row. Traffic counts were conducted simultaneously with the measurements.

Results. The investigators performed several types of analyses using the measurement and survey data. Each row on either side of the freeway was assigned pre-barrier and post-barrier noise levels based on the measurements. The respondents were grouped together within each row, neglecting the effects of reduced barrier attenuation near the ends of the barriers. The analysis focused on mean annoyance scores for each row; detailed analysis was performed using the results for the east side only.

Curves were derived for mean annoyance (the highest annoyance reported for any time of day) as a function of daytime Leq and daytime L10. Clearly the annoyance scores were lower after construction of the noise barriers, especially for the first and second rows. However, it is not clear from the results whether people under-reacted or over-reacted to the change, since the first and second row data was grouped together in deriving the curves.

A.2.4 Wuppertal/Düsseldorf

Kastka, J.; and Paulsen, R.: 1979. Untersuchung über die Subjektive und Objektive Wirksamkeit von Schallschutzeinrichtungen und ihre Nebenwirkungen auf die Anlieger. (An Investigation of the

Subjective and Objective Effectiveness of Noise Protection and its Effectiveness for the Requester). Report of the Institut für Hygiene. Institut für Hygiene, Universität Düsseldorf. [GER-282]

Langdon, F.J.; and Griffiths, I.D.: 1982. Subjective Effects of Traffic Noise Exposure, II: Comparisons of Noise Indices, Response Scales, and the Effects of Changes in Noise Levels. J. Sound Vibration, Vol. 82, no. 2, p. 171-180. [UKD-157 UKD-268 GER-282]

Kastka, J.; Buchta, E.; Paulsen, R.; and Ritterstaedt, U.: 1984. Vergleichende Untersuchungen zur Lärmbelästigung von Autobahnen und anderen Straβen. (Comparative Studies on Noise Nuisance Emanating from Autobahns and Other Highways). Forschung Straβenbau und Straβenverkehrstechnik Number 432, Bonn. [GER-164 GER-282 GER-281 GER-847 GER-849]

Description. This study concerns the response to changes in traffic noise level caused by construction of noise barriers and earth berms at locations in the German cities of Wuppertal and Düsseldorf. Noise measurements and surveys were conducted in 7 general areas between 1974 and 1975, at least a year before construction, and again in 1979 a year after construction was completed. Between the 7 areas, the mean reduction in noise exposure was 7 dB.

174 people were interviewed between the 7 areas before the change and 138 were interviewed afterwards. During the interviews respondents were asked approximately 33 questions relating to annoyance due to traffic noise. The answers to these questions were used to construct three composite scales. One scale measured the sensory/irritation annoyance component (intensity, frequency, and other characteristics of the noise), another measured the subjective disturbance to well-being caused by the noise (anger, disturbance to sleep, and other similar characteristics), and the final scale measured effects of traffic noise on communication and secondary effects such as vibration.

Noise measurements were conducted in each of the 7 areas. In each area at least one 24-hour measurement was performed, in addition to a number of 10-20 minute measurements. Contours of 24-hour Leq were constructed from the measurements, and a representative noise level was chosen for each of the areas. The measurements were conducted at the same locations before and after the changes.

Results. The authors derived linear dose-response curves for the before and after conditions for each of the three annoyance scales. The curves showed that people were more annoyed by higher noise levels, but that they became more sensitive to noise the after the change. That is, the after curves were shifted to the left of the before curves, indicating that after the change noise of a particular level caused more annoyance than before. Another way to view this is that although the noise barriers reduced annoyance by reducing noise levels, they did not reduce annoyance as much as might be expected using just the before data to derive a dose-response curve. The size of the shift varied between the three scales and was approximately 2 to 5 dB.

In their 1982 paper, Langdon and Griffiths published the German data along with data from other studies and speculated that although other studies indicated a decrease in sensitivity to noise after a reduction, there may be a different outcome when the noise is reduced using barriers rather than at the source.

A.2.5 10-Site Traffic Change

Mackie, A.M.; and Griffin, L.J.: 1977. Before and After Study of the Environmental Effects of Tring By-pass. Department of the Environment. TRRL Report LR 589. Transport and Road Research Laboratory, Crowthorne, England. [UKD-268 UKD-724]

Mackie, A.M.; and Forster, M.: 1978. Environmental Effects of Traffic in Ludlow, Salop. TRRL Report SR 245. Transport and Road Research Laboratory, Crowthorne, England. [UKD-268 UKD-831 UKD-725]

Mackie, A.M.; and Griffin, L.J.: 1978a. Environmental Effects of Traffic: Case Study at Mere, Wiltshire. TRRL Report SR 428. Transport and Road Research Laboratory, Crowthorne, England. [UKD-268]

Mackie, A.M.; and Griffin, L.J.: 1978b. Environmental Effects of By-Passing Small Towns - Case Studies at Boughton, Dunkirk and Bridge. TRRL Report SR 349. Transport and Road Research Laboratory, Crowthorne, England. [UKD-268]

Griffiths, I.D.; Langdon, F.J.; and Swan, M.A.: 1980. Subjective Effects of Traffic Noise Exposure: Reliability and Seasonal Effects. J. Sound Vibration, Vol. 71(2), pp. 227-240. [control sites for UKD-268]

Mackie, A.M.; and Davies, C.H.: 1981. Environmental Effects of Traffic Changes. TRRL Report LR 1015. Transport and Road Research Laboratory, Crowthorne, England. [UKD-268 UKD-724]

Langdon, F.J.; and Griffiths, I.D.: 1982. Subjective Effects of Traffic Noise Exposure, II: Comparisons of Noise Indices, Response Scales, and the Effects of Changes in Noise Levels. J. Sound Vibration, Vol. 82, no. 2, p. 171-180. [UKD-157 UKD-268 GER-282]

Griffiths, I.D.; and Raw, G.J.: 1989. Adaptation to Changes in Traffic Noise Exposure. J. Sound Vibration, Vol. 132, pp. 331-336. {ADD 6/90} [UKD-237 UKD-268 UKD-297 UKD-298]

Description. This study consists of a series of interviews and measurements of highway noise conducted in England. There were three main efforts involved in this study. First, between 1975 and 1978 "before-after" studies were conducted and reported by Mackie and Davies in their 1981 report. The purpose of these studies was to measure the effects of decreases in traffic in small towns, primarily due to the opening of bypasses that diverted through traffic (largely trucks) from small towns. Studies where interviews and measurements were conducted both before and after traffic changes were:

Tring	by-pass
Mere	by-pass
Boughton	by-pass
Bridge	by-pass
Lewes	by-pass
Stafford	inner relief road
East Grinstead	inner relief road
Ludlow	by-pass
Leeds-A58	lorry routing
Leeds-A64	lorry routing

Second, noise measurements and interviews were conducted at 8 sites in suburban London to develop a baseline curve. Langdon and Griffiths compared the results of these measurements to Mackie's in their 1982 paper to determine whether or not people overreacted to a decrease in noise exposure:

Ilford
Epsom
SW20
SW19
N9
Sutton
Kingston
Wembley

Third, Griffiths and Raw conducted another set of "after" studies at Boughton, Bridge, Mere, Lewes, and East Grinstead 7 to 9 years after their changes in noise exposure to determine whether or not there was any long-term adaptation to noise levels. That is, they sought to determine whether or not the annoyance scores that had dropped significantly at the time of the decrease in traffic had risen up to what might be predicted using a baseline curve.

In the first series of interviews there were two sets of interviews: one shortly before the change in traffic, and one a few months afterwards. Pedestrians and office workers were interviewed, as well as residents, but the analysis and results are based on residents' responses only. The primary question concerning noise asked the respondent how much traffic noise bothered them: "not at all," "not very much," "quite a lot," or "very much." In the second series of interviews (in London), residents rated noise on a 7-point *and* a 4-point scale so that the results could be compared with a variety of studies. At certain sites interviews were conducted at four different times in a year. The third series of interviews used the same 4-point scale as before. The sample size varied between sites, but was typically 100 to 200 respondents.

All measurements were reported in terms of 18-hour L10. For the measurements in London, a number of metrics were measured, including Leq, and the correlation between metrics was found to be very high. Typically measurements at one or two locations were used to characterize the entire sample. The measurements were generally used to calibrate a computer model that was then used to predict noise exposure.

Results. Three references summarize the three different sets of conclusions arrived at based on these data. Mackie and Davies analyzed answers to a question on "nuisance," but this question was not noise-specific. Langdon and Griffiths supplemented the previous data with their measurements in London. From the London data they derived a baseline curve. They compared the change in noise exposure data to this curve and found it to be significantly different. That is, they found that people overreacted to a change. Based on another set of "after" measurements Griffiths and Raw concluded that the overreaction had dissipated, and the study populations had begun to, but not completely returned to steady-state conditions.

A.2.6 Ohio Highway

Weinstein, N.D.: 1980. Individual Differences in Critical Tendencies and Noise Annoyance. J. Sound Vibration, Vol. 68, no. 2, pp. 241-248. [USA-156]

Weinstein, Neil D.: 1980. Personal and Family Adjustment to Urban Noise. Final Report, National Institute of Mental Health Grant No. R01MH27298. [USA-156]

Weinstein, N.D.: 1982. Community Noise Problems: Evidence Against Adaptation. J. Env. Psych., Vol. 2, pp. 87-97. [USA-156]

Description. This study concerns adaptation to an increase in noise exposure caused by the opening of a freeway in a suburban neighborhood in Ohio. The freeway had been planned in 1960 and was opened in January 1978. Since the freeway was a short (2 mile) section linking other heavily-used freeways, traffic volumes quickly rose when the freeway opened, and then remained relatively constant. Residents within the 70 dB(A) (peak-hour L10) contour were interviewed a few months before the freeway opened, 4 months after it opened, and 16 months after it opened. The study was designed specifically to determine how response to noise changed over time after the freeway opened.

There were 3 separate groups of respondents. A panel group of 113 respondents was interviewed on three occasions (before the opening, 4 months after, and 16 months after). One control group of 50 respondents was interviewed only at the time of the second set of interviews, and another control group of 47 respondents was interviewed only at the time of the final set of interviews. The interview consisted of a number of questions on noise from the new freeway, including questions about noise effects (primarily activity interference), annoyance, and noise focus (questions about how much the respondents found themselves thinking about or discussing noise).

Noise measurements were conducted 4 and 16 months after the freeway opened at one position 13 m from the near edge of the closest lane of traffic. The measurements were conducted for 9 hours in the morning and evening. The measurement results, reported in terms of hourly Leq, indicated that noise levels were relatively constant between the sets of interviews. The Leq for the two periods differed by less than 1 dB: 74.1 dB(A) in June 1978 versus 74.8 dB(A) in June 1979. Short-term (5 minute) noise measurements were conducted at 34 positions to characterize conditions throughout the study area. Noise measurements were not carried out before the freeway opened, but a measurement was conducted along a quiet street in the same area, thought to be representative of the pre-freeway conditions. The daytime Leq at this position was approximately 54 dB(A), or approximately 19 dB lower than at the long-term measurement position.

Results. The interview results were analyzed by constructing three different composite scale from the responses: one for effects, one for annoyance, and one for focus. However, the correlation between the scales was found to be high, so the scales were summed and the sum for each respondent was used to indicate their total disturbance due to noise.

The mean of the total disturbance rose from 14.86 to 16.71 units for the panel group between the second and third surveys. The corresponding means for the control groups were 18.50 and 17.15 units. The standard deviations on the mean ranged from 10.77 to 12.25. The difference in the means between the two control groups was found to be statistically insignificant. However, the mean disturbance of the panel group was found to be low for the second survey; Weinstein hypothesized that this is related in some way to the fact that the panel group had been interviewed before. The author concludes that there is not, in any case, any evidence that the respondents adapted to higher noise levels from the freeway, at least not between the second and third interviews.

The treatment of mediating variables was quite complete in this study. Much of the analysis focused on respondents' "critical tendencies." Weinstein calculated respondents' critical tendencies, a parameter reflecting their predisposition towards expressing perceived annoyance, based on answers from the first round interviews to a number of questions concerning attitudes and expectations. The critical tendencies were then used to reduce the scatter in the relationship between noise and annoyance experienced after the change .

A.2.7 6-City Traffic Change

Kastka, J.: 1980. Noise Annoyance Reduction in Residential Areas by Traffic Control Techniques. Tenth International Congress on Acoustics, p. C2-12.2 [GER-246]

Kastka, J.: 1981. Zum Einfluβ verkehrsberuhigender Maβnahmen auf Lärmbelästung und Lärmbelästigung. (The influence of traffic calming on traffic noise and its nuisance effect). Zeitschrift für Lärmbekämpfung, Vol. 28, pp. 25-30. [GER-246]

Description. This is a study of a response to changes in traffic noise at 50 areas in 6 cities in Germany. The study was a part of a larger program to reduce the volume of through traffic and traffic speeds in 30 cities in Nordhein-Westfalen in Germany. These reductions were accomplished through a variety of measures, including instituting one-way streets and cul-de-sacs, narrowing streets, adding traffic signals, and other measures. Residents in the 50 areas were interviewed before and a year after the changes. The mean 24-hour Leq was reduced only approximately 1 dB by the traffic changes. We do not have exact dates for when the changes took place, but estimate that it was around 1978.

Approximately 1700 people were interviewed for each interview round. The interviewers avoided interviewing the same people twice. During the interviews respondents were asked approximately 20 questions relating to annoyance due to traffic noise. The answers to these questions were used to construct two composite annoyance scales. One scale measured the sensory/irritation annoyance component (intensity, frequency, and other characteristics of the noise), and the other scale measured the subjective disturbance to well-being caused by the noise (anger, disturbance to sleep, and other similar characteristics).

Noise measurements were conducted in each of the 50 areas. In each area 2 to 4 24-hour measurements were performed, in addition to 3 to 16 one-hour measurements. Contours of 24-hour Leq were constructed from the measurements, and a representative noise level was chosen for each of the 50 areas. The measurements were conducted at the same locations before and after the changes.

Results. The investigators derived linear dose-response curves for the before and after conditions for each of the two annoyance scales. The after curves were shifted relative to the before curves, and indicated that the respondents had become less sensitive to noise after the changes. Although the mean reduction in noise level was only 1 dB, the respondents' annoyance dropped by an amount expected from (based on the before curve) an 8 dB reduction. However, the investigators concluded that they could not attribute the change in response solely to the change in noise level. A plot of the change in annoyance versus the change in noise level showed no correlation. The investigators discussed the possibility that there may have been some sort of "halo effect," whereby people were aware that the government was spending money to try to help them, and this affected their assessment of the noise.

A.2.8 Brisbane Reduction

Brown, A.L.; Hall, A; and Kyle-Little, J.: 1985. Response to a Reduction in Traffic Noise Exposure. J. Sound Vibration, Vol. 98, pp. 235-246. [AUL-264]

Description. This study concerns a change in noise exposure along a street in Brisbane Australia. In 1979, traffic levels on this residential street dropped considerably upon the opening of a nearby freeway extension, from 20,00 vehicles per day to 3,000 vehicles per day. The purpose of the study was to compare the change in level of annoyance caused by traffic noise for the group of people who experienced the change in noise exposure with the change that would be predicted based on sampling two other control groups, one exposed to the same "before" noise level, and one exposed to the same "after" noise level.

Three sets of interviews were conducted. The experimental group (the group exposed to the change) was interviewed once at least 15 months after traffic volumes dropped. This group included 49 respondents. The two control groups were each interviewed once. The "before" control group (the group exposed to a higher traffic volume) consisted of 52 respondents, and the "after" control group consisted of 40 respondents. Each group consisted of residents whose buildings were all approximately the same distance from the centerline of the roadway. Respondents were asked to rate their level of annoyance on a 7-point verbal scale (not at all, very little, a small amount, a fair amount, quite a bit, a lot, or a great deal). Respondents in the experimental group were asked about their annoyance at present and before the freeway extension was opened.

Noise measurements were conducted for the experimental group after the change and the two control groups. Each group was assumed to be exposed to the same noise level. Noise projections were made for the experimental group before the change based on traffic counts. The noise metrics measured were L10-12hrs (7:00 to 19:00) and L10-18hrs (6:00 to 24:00). DNL was projected for comparison with the Schultz curve.

Results. The investigators based their conclusions primarily on an examination of the experimental group's retrospective judgements. In recalling their level of annoyance before the change in noise exposure, the respondents in the experimental group recalled much higher levels of annoyance than the control group that was exposed to comparable levels. Compared to the control group exposed to lower noise levels, the experimental group had a slightly lower level of high annoyance (2% versus 4%, where high annoyance is defined as the top two of seven categories of response). Except for the retrospective judgements, all of the data points correspond closely with the Schultz curve.

A.2.9 Brisbane Increase

Brown, A.L.: 1987. Responses to an Increase in Road Traffic Noise. J. Sound Vibration, Vol. 117, pp. 69-79. [AUL-265]

Description. This study concerns a change in noise exposure along a street in Brisbane Australia. In 1980, traffic levels on this residential street increased considerably when the street was connected to other roadways so that it could function as a through route for road traffic. The traffic volume rose from 1,999 vehicles per day before the change to 7,925 vehicles per day 7 months after the change, and 11,238 vehicles per day 19 months after the change. The purpose of the study was to measure the change in annoyance as noise exposure increased, to determine whether or not respondents adapted to the noise, and to examine respondents' retrospective judgements concerning annoyance.

Three sets of interviews were conducted. The same group of people was interviewed 2 months before the connection was completed, 7 months after it was completed, and 19 months after it was completed. The group consisted of 20 respondents; the initial interview included 22 respondents, but one person moved away, and another refused further interviews. Respondents were asked to rate their level of annoyance on a 7-point verbal scale (not at all, very little, a small amount, a fair amount, quite a bit, a lot, or a great deal). Respondents were asked about their annoyance at present and before the connection was opened.

Noise measurements and traffic counts were conducted for the three interview periods. The entire group was assumed to be exposed to the same noise level. The noise metrics measured were Leq-peak hr, L10-peak hr, Leq-24hrs, L10-18hrs and DNL. DNL was 61 dB(A) at the time of the first interview, 69 dB(A) at the time of the second, and 71 dB(A) at the time of the third.

Results. The investigators placed the greatest emphasis on the respondents' retrospective judgements. Respondents consistently reported in their retrospective judgements that they were less annoyed than had actually been measured in the first interview. Aside from the retrospective judgements, 15% of the respondents reported they were highly annoyed (the top two categories of the scale) in the first interview. 45% reported high annoyance in the second interview, and 55% reported high annoyance in the third interview. This indicates that there was no adaptation between 7 months after the connection opened and 19 months after the connection opened. The results of the first interview correspond closely with the Schultz curve; the results of the second and third indicate levels of annoyance somewhat higher than would be predicted using the Schultz curve.

A.2.10 8-Site Traffic Change

Griffiths, I.D.; and Raw, G.J.: 1984. Subjective Response to Decreases in Traffic Noise Exposure. Proceedings of the Fourth Congress of the Federation of Acoustical Societies of Europe, pp. 343-346. [UKD-237]

Griffiths, I.D.; and Raw, G.J.: 1986. Community and Individual Response to Changes in Traffic Noise Exposure. J. Sound Vibration, Vol. 111, pp. 209-217. [UKD-237]

Griffiths, I.D.; and Raw, G.J.: 1989. Adaptation to Changes in Traffic Noise Exposure. J. Sound Vibration, Vol. 132, pp. 331-336. [UKD-237 UKD-268 UKD-297 UKD-298]

Raw, G.J.; and Griffiths, I.D.: 1990. Subjective Response to Changes in Road Traffic Noise: A Model. J. Sound Vibration, Vol. 141, pp. 43-54. [UKD-237]

Description. This is a study of response to changes in traffic noise, and is similar in many ways to the 10-Site Traffic Change study. Traffic noise and human response were measured at 8 sites in the south of England. At each of the sites a change occurred; there were noise exposure decreases due to by-pass openings at 6 sites, and increases due to new roads at 2. A second set of measurements and interviews was performed 17 to 22 months after the change in noise exposure to measure residents' degree of adaptation.

A total of 469 residents were interviewed. The first interview took place 1 to 7 months before the change in noise exposure. The second interview took place 2 to 3 months after the change. The same respondents were interviewed each time. Twice in each interview the respondent was asked

"How satisfactory do you find the level of traffic noise which you can hear when you are in your home?" The response was given on a 7-point scale with the endpoints labeled "definitely satisfactory" and "definitely unsatisfactory." 17 to 22 months after the change in noise exposure, another interview was conducted at 3 of the sites where there had been no significant further changes in noise exposure. 90 interviews were conducted (out of a possible 126 respondents from the second interview) at that time.

All measurements were reported in terms of 18-hour L10. Sound level measurements were conducted at representative community locations, and modelling was performed based on the measurements to characterize the noise exposure at each residence in the surveys.

Results. The 1986 paper reports on the results of the first two interviews - before and shortly after the change in noise exposure. The investigators concluded that (and developed linear equations to describe their conclusion) the respondents who experienced a decrease in noise exposure reported a lower level of dissatisfaction than would be expected based on a baseline curve derived from the first-round data. Likewise, respondents who experienced an increase in noise exposure reported a higher level of dissatisfaction than would be expected based on the baseline curve.

The analysis was based on mean dissatisfaction scores. Interestingly, the correlation between the two questions on dissatisfaction in the first interview was only 0.725. The response scale was linearized and results of the two questions were averaged. A dose was assigned to each respondent, although it appears that both individual and grouped responses were examined.

The 1989 paper described the supplemental measurements performed to test medium-term adaptation at 3 sites. The authors concluded that dissatisfaction had not changed significantly at these sites. Thus, no adaptation to the change in noise exposure had occurred in a period of 17 to 22 months. The 1990 paper presents a model for explaining why people might react the way they do to a change in noise exposure.

A.2.11 14-Site Traffic Change

Baughan, Christopher; and Huddart, Linda: 1992. Effects of Changes in Exposure to Traffic Noise. PTRC Annual Summer Meeting, Seminar B, "Environmental Issues." [UKD-325 UKD-351]

Baughan, Christopher; and Huddart, Linda: 1993. Effects of Traffic Noise Changes on Residents' Nuisance Ratings. In Noise and Man '93: Noise as a Public Health Problem (Proceedings of the Sixth International Congress), Volume 2, pp. 585-588. INRETS, Arcueil, France. [UKD-325 UKD-351]

Description. This study involves measurements and surveys at 14 sites where there was an increase or decrease in noise exposure. The changes in noise exposure were a result of roadway traffic changes. At five of the sites there were noise exposure increases; at nine there were decreases.

A total of 33 to 50 residents were interviewed at each of the sites. The first round of interview occurred 2 or 3 months before the change in noise exposure occurred. The second round of interviews occurred 2 or 3 months after the change. The same respondents were interviewed each time. The respondent was asked "How satisfactory do you find the level of traffic noise which you can hear when you are in your home?" The response was given on a 7-point scale with the endpoints labeled "definitely satisfactory" and "definitely unsatisfactory."

All measurements were reported in terms of 18-hour L10. Sound level measurements were conducted at one representative locations per site. Measurement results were reported in one of the references, but it appears that modelling was used to characterize the noise exposure for the data analysis. The measured change in noise exposure ranged from -10 to +5 dB.

Results. The results of the study were consistent with the 8-Site Traffic Change study. Respondents typically over-reacted to changes in noise exposure relative to what would be expected based on steady-state conditions. A baseline curve based on an undocumented TRL 35-site study was used for comparison with the results from the 14 change sites. Results were presented in terms of the linearized dissatisfaction score. Curves were derived relating change in dissatisfaction as a function of change in noise exposure. The first order curves had a non-zero intercept (in other words, they predicted a change in response even when there is no change in noise exposure), so the investigators also presented a third order curve with an intercept of zero. In addition, the authors derived curves that included the 8-Site Traffic Change data.

A.2.12 French Barriers

Vincent, Bruno; and Champelovier, Patricia: 1993. Changes in the Acoustic Environment: Need for an Extensive Evaluation of Annoyance. In Noise and Man '93: Noise as a Public Health Problem (Proceedings of the Sixth International Congress), Volume 2, pp. 425-428. INRETS, Arcueil, France. [FRA-346]

Description. This study concerns change in response due to a decrease in traffic noise exposure caused by construction of noise barriers. At two sites in Frances glass and concrete noise barriers and a low noise surface were constructed in 1991. Interviews were conducted before (in January and March) and after (in June and September) construction of the noise barriers. Measurements were conducted at each of the sites.

A total of 75 people were interviewed at the two sites. The survey included a number of questions concerning activity interference and annoyance due to noise. Also, respondents rated their expectations concerning the planned noise barriers before construction, and their actual experience afterwards.

Noise measurements were conducted before and after the measurements. The 20-hour Leq was an average of approximately 65 before the barriers and 56 afterwards. The reference for this study does not include details concerning the measurements.

Results. The interview results were reported in terms of the percentage people giving certain responses before and after construction of the barriers. Before construction of the barriers, mean annoyance was 3.25, and 22% of the respondents were highly annoyed. After the 8 dB drop in noise levels, the mean annoyance was 2.97, and 8% of the respondents were highly annoyed.

The investigators emphasize that annoyance scores alone do not account for the difference a noise barrier makes. They point to differences in behavior patterns indicating high annoyance as more useful indications of the affect of the noise barriers.

A.3 Rail Investigations

A.3.1 Shinkansen

Sone, Toshio; Kono, Shunichi; Nimura, Tadamoto; Kameyama, Shunichi; and Kumagai, Masazumi: 1973. Effects of High Speed Train Noise on the Community Along a Railway. J. Acoust. Soc. Japan, Vol. 29, pp. 214-224. Translation available in BBN Technical Information Report 87. Bolt Beranek and Newman, Cambridge. [JPN-065]

Nimura, T.; Sone, T.; and Kono, S.: 1973. Some Consideration on Noise Problems of High-Speed Railways in Japan. Proceedings of Inter-Noise 73, pp. 298-307. [JPN-065]

Nimura, T.; Sone, T.; Ebata, M.; and Matsumato, H.: 1975. Noise Problems with High Speed Railways in Japan. Noise Control Engineering, Vol. 5, no. 1, pp. 5-11. [JPN-065]

Nimura, T.; Sone, Toshio; and Kono, Shunichi: 1981. Evaluation of Train/Railway Noise. Proceedings of Inter-Noise 81, pp. 803-812. [JPN-065 JPN-064 JPN-101]

Description. This study concerns response to noise from the Tokaido and Sanyo Shinkansen lines. The Tokaido Line was built in 1964 and is 515 km long; the Sanyo line was built in 1972 and is 161 km long. Both lines had a maximum speed of 210 km/hr. As a newer line, the Sanyo line was somewhat quieter than the Tokaido Line when it opened. Surveys of residents near these lines were conducted in July 1972, 4 months after the opening of the Sanyo Line and 8 years after the opening of the Tokaido Line. The purpose of the study was determine how people reacted to noise from the Shinkansen, and to compare the results for the two different lines.

A total of 424 people were interviewed. There were 182 respondents along the Sanyo Line (87 were less than 50 m from the centerline of the tracks) and 242 along the Tokaido Line (150 were located less than 50 m from the centerline of the tracks). Respondents were asked about their attitudes concerning their neighborhood, their reactions to train noise, and their attitudes to noise in general. One question asked the respondent to rate on a 7-point scale the extent to which they thought the railroad was noisy.

Measurements of train noise were conducted at three different times, but the data used for comparison with the questionnaire were obtained at the time of the interview. The peak outdoor noise level at the same distance from the tracks as each house was measured at the time of the interviews (it is not clear how exactly how many measurement positions there were or how many trains were measured at each position). A relationship was derived for estimating peak noise level as a function of distance for each area, and this relationship was used to estimate peak noise level at each house.

Results. The investigators related noise exposure (in PNL) to annoyance and a number of interference-related responses. For other responses besides annoyance, the "Likert" method was used in the analysis. The "neutral point" on the Likert scale was reported separately for each line and each response. The neutral point for annoyance was 73 dB(A) for the Tokaido Line, and 69 dB(A) for the Sanyo Line. Over all of the responses the difference was 5 to 6 dB.

The investigators pointed out that peak noise level does not account for the number of operations on each line: 200 per day on the Tokaido Line and 80 per day on the Sanyo Line. Accounting for this difference using WECPNL, residents along the Sanyo Line are approximately 10 dB more sensitive than residents on the Tokaido Line. The authors imply that this difference is likely a result of habituation.

A.3.2 Zoetermeer

van Dongen, J.E.F.; and van den Berg, R.: 1980. De Gewenning aan de Nieuwe Spoorlijn te Zoetermeer. (The Habituation to the Noise of a Newly Opened Railroad at Zoetermeer). Report D 50. IMG- TNO, Delft, Netherlands. [NET-195]

de Jong, R.G.: 1983a. Some Developments in Community Response Research Since the Second International Workshop on Railway and Tracked Transit System Noise in 1978. J. Sound Vibration, Vol. 87, pp. 297-309. [NET-106 NET-153 NET-195]

Description. This study concerns annoyance due to noise from a new commuter rail line, "the Sprinter," in Zoetermeer, Holland. The line opened in May 1977 and passes through a suburban area outside the Hague. Because there are frequent stops along the line, train speeds are relatively low. Also, there is little nighttime activity on the line; there are no trains between 12 AM and 6 PM.

Approximately 133 respondents were interviewed on three separate occasions: before the railway opened, 4 months after it opened, and 1-1/2 years after it opened. The same respondents were interviewed each time, although 15 newcomers who moved in after the rail line opened were included as a separate group. In the first round of interviews there were 425 respondents, and in the second round there were 299. Respondents were asked to rate specific and non-specific noise-induced nuisance. Specific nuisance was a composite measure based on 7 different questions related to activity interference. Non-specific nuisance was based on respondents' reaction to railroad noise, ranked on a 6-point verbal scale.

Noise measurements were conducted once, in the Spring and Summer of 1978. It was assumed that train noise levels were constant after the line opened. The noise metrics measured included Lmax, Leq-24 hrs, Leq-24hrs minus L95-daytime background, Leq-24hrs minus L95-evening background, and Lmax minus L95-evening background. Leq-24hrs was calculated as the maximum of the following: daytime Leq, evening Leq plus 5, and nighttime Leq plus 10. Leq-24hrs varied from 40 to 60 dB(A).

Results. The investigators concluded that there is a habituation (adaptation) to noise level. This result was based on a reduction in noise-induced nuisance measured between the second and third interviews, and a lower level of nuisance for respondents who had moved in since the opening of the rail line than respondents who had been in the neighborhood since before the rail line opened.

A.4 Other Investigations

A.4.1 Welsh Village (Pyrotechnic)

Webb, D.R.B.; and Warren, C.H.E.: 1967. An Investigation of the Effect of Bangs on the Subjective Reaction of a Community. J. Sound Vibration, Vol. 6, no. 3, pp. 375-385. [UKD-010]

Description. This study concerns annoyance due to noise from explosions in a Welsh village. The study was conducted in 1963 under the code name Exercise Yellowhammer. Over the course of 14 weeks explosive charges were fired suspended from a balloon 1750 to 2770 feet from nearby residences. The charges were fired on Mondays and Tuesday, primarily in the daytime between 9:30 and 15:30. Each week approximately 50 charges were fired. However, the intensity, number and timing of the charges were purposefully changed on certain weeks.

283 people lived in the community and participated in the study. The community was divided into 4 samples of approximately equal size and demographics. Each week of the study, on Thursdays and Fridays, all of the respondents in one of the groups were interviewed. The survey asked whether the bangs during that week bothered or annoyed the respondent "not at all," "only a little," moderately," or "very much." The respondents had been notified ahead of time that the government would be conducting a study, and they had already been exposed to the sounds of explosions.

Noise measurements were conducted at 3 positions for 40% of the explosions. Microphones were placed in holes dug in the ground and the trace from the oscilloscope was photographed for each explosion measured. The peak overpressure in lbs/ft^2 was reported for each position for each charge weight, and the relationship between peak overpressure and distance was derived. No A-weighted or C-weighted sound levels were reported. The relative sound levels from explosions in different weeks may be calculated based on variation in the number and size of charges.

Results. The investigators showed that, over the course of the study, the percentage of people annoyed by the explosions steadily decreased, except for weeks that noise levels were higher due to variations in the charge timing, frequency, or number. There were 8 weeks in which the "standard"

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13. ABSTRACT (Maximum 200 words)
The purpose of this study is (1) to investigate the current body of knowledge encompassing two related topics: (a) to what extent can we reliably predict the change in people's attitudes in response to an abrupt change in noise exposure, and (b) after the change, is there a decay in the abrupt-change effect whereby people's attitudes slowly shift from their initial reaction to a steady-state value? and (2) to provide recommendations for any future work that may be needed. The literature search located 23 studies relating to one or both of the above topics. These prior studies shed considerable light on the current ability to predict initial reaction and decay effects. The literature makes one point very clear: Great care in both experimental design and data analysis is necessary to produce credible, convincing findings, both in the reanalysis of existing data and for planning future data acquisition and analysis studies. New airport studies must be designed to minimize nuisance variables and avoid past design features that may have introduced sufficient unexplained variance to mask sought after effects. Additionally, the study must be designed to tie in with previous investigations by incorporating similar survey questions and techniques.

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program was followed, and 6 weeks when the program was varied. In Week 1, approximately 50% of people surveyed were annoyed "at all." By Week 13 the figure had dropped to approximately 20%. The percentage of people "considerably" annoyed dropped by approximately 8%. Two and threefold changes in frequency and evening explosions increased annoyance significantly.